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W J McGEE, *Editor*

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Brochure.	Pages.	Plates.	Figures.	Price to Fellows.	Price to the Public.
The Stratigraphy of the "Quebec Group." R. W. Ells	453–468	10	------	$0.30	$0.55
Some additional Evidences bearing on the Interval between the Glacial Epochs. T. C. Chamberlin	469–480	------	------	.15	.30
The Cuboides Zone and its Fauna; a Discussion of Methods of Geologic Correlation. H. S. Williams	481–500	11–13	------	.45	.90
The Calciferous Formation in the Champlain Valley. Ezra Brainerd and H. M. Seely. With a Supplement on the Fort Cassin Rocks and their Fauna. R. P. Whitfield	501–516	------	------	.20	.40
Proceedings of the New York Meeting. J. J. Stevenson, *Secretary*. (With Index, Title-page, List of Contents, etc., for the Volume	517–593 i–xii	------	------	1.25	2.45

Volume 2, covering the work of the Society for the year 1890, is now complete. It comprises the following brochures:

Brochure.	Pages.	Plates.	Figures.	Price to Fellows.	Price to the Public.
Proceedings of the Semi-Annual Meeting held at Indianapolis. J. J. Stevenson, *Secretary*	1–30	------	1–2	$0.35	$0.70
The Cuyahoga Shale and the Problem of the Ohio Waverly. C. L. Herrick	31–48	1	------	.25	.45
The Structure of a Portion of the Sierra Nevada of California. G. F. Becker	49–74	------	1–13	.35	.65
Phosphate Deposits of the Island of Navassa. E. V. D'Invilliers	75–84	------	1	.15	.30
A Last Word with the Huronian. Alexander Winchell	85–124	------	1–3	.45	.90
The Nickel and Copper Deposits of Sudbury District, Canada. Robert Bell; with an appendix on The Silicified Glass-Breccia of Vermilion River, Sudbury District. Geo. H. Williams	125–140	------	1–4	.20	.40
The Overthrust Faults of the Southern Appalachians. C. Willard Hayes	141–154	2–3	1	.30	.55
The Structure of the Blue Ridge near Harper's Ferry. H. R. Geiger and Arthur Keith	155–164	4–5	------	.20	.40
Note on the Geological Structure of the Selkirk Range. G. M. Dawson	165–176	------	1	.15	.30
Graphic Field Notes for Areal Geology. Bailey Willis	177–188	6	------	.20	.35
Antiquities from under Tuolumne Table Mountain in California; Notes on the Early Cretaceous of California and Oregon. G. F. Becker	189–208	7	1	.30	.60
The Relation of Secular Rock-Disintegration to Certain Transitional Crystalline Schists. Raphael Pumpelly	209–224	------	1–4	.20	.35
The Geotectonic and Physiographic Geology of Western Arkansas. Arthur Winslow	225–242	8	1–9	.35	.65
Glacial Lakes in Canada. Warren Upham	243–276	------	------	.35	.70

Irregular Publications.

In the interests of exact bibliography, the Society takes cognizance of all publications issued either wholly or partly under its auspices. Each author of a memoir receives 30 copies, and is authorized to order any additional number at a slight advance on cost of paper and presswork; and these separate brochures are identical with those of the editions issued and distributed by the Society. Contributors to the proceedings also are authorized to order any number of separate copies at a slight advance on cost of paper and presswork; but these separates are bibliographically distinct from the brochures issued by the Society.

The following separates of parts of Volume 2 have been issued:

Editions uniform with the Brochures of the Bulletin.

Pages	31- 48, plate	1— 30	copies.	January	12,	1891.
"	49- 74,	130	"	"	16,	"
"	75- 84,	30	"	"	29,	"
"	85-124,	200	"	February	9,	"
"	125-140,	260	"	"	7,	"
"	141-154, plates	2, 3—105	"	March	3,	"
"	155-164, "	4, 5— 80	"	"	3,	"
"	165-176,	200	"	February	11,	"
"	177-188, plate	6— 30	"	March	3,	"
"	189-208, "	7—155	"	"	3,	"
"	209-224,	280	"	February	20,	"
"	225-242, plate	8—130	"	March	4,	"
"	243-276,	80	"	"	7,	"
"	277-292, plates	9, 10—180	"	"	24,	"
"	293-300, plate	11— 30	"	"	25,	"
"	301-322, "	12— 60	"	"	24,	"
"	323-330,	50	"	"	24,	"
"	331-338,	60	"	"	25,	"
"	339-348,	60	"	"	24,	"
"	349-364, plate	13— 30	"	"	25,	"
"	365-382, "	14—130	"	May	6,	"
"	383-414, "	15—130	"	April	3,	"
"	415-430,	130	"	"	14,	"
"	431-450, plate	16— 80	"	May	5,	"
"	451-456, "	17—230	"	"	13,	"
"	457-464, "	18—330	"	"	9,	"
"	465-476, "	19—205	"	"	6,	"

layers of such clay and brick-red loam like that of the upper member. This silicious clay sometimes contains well-preserved leaf impressions and other plant fossils. It is largely used in the manufacture of pottery in northern Mississippi, western Kentucky, and particularly in western Tennessee. (3) The basal member is commonly made up of irregularly stratified lead-colored or gray silicious clay (less pure than that of the middle member), red or brown sand, gray silt, etc. The middle and lower members commonly merge insensibly, as do the upper and middle members in most sections; but sometimes a sharp division plane demarks the upper loam and the subjacent clays, the clay strata are truncated as if by erosion, and pellets and lenses of the clay are incorporated in the overlying loam. This relation suggests unconformity; but it probably represents nothing more than a common type of transition from slack-water deposits to the products of stronger currents. From the Big Black river to the Ohio the brick-red loams and sands and the attendant gravel beds form the surface over a zone 20 to 50 miles broad lying east of the limits of the newer Columbia formation, though they have been deeply and widely trenched by all of the larger rivers. The thickness of the formation at Holly Springs, Mississippi, and La Grange, Tennessee, is about 200 feet, while the artesian borings at Memphis indicate a thickness of no less than 435 feet for the middle and lower members. North of the Ohio, in southern Illinois, the formation is a pebbly red loam or sand, sometimes distinctly stratified. In central Arkansas, notably at Little Rock and about Malvern, pebbly, red loams, undoubtedly representing the same formation, are occasionally found overlying the glauconitic Eocene sands and the older formations alike, and are overlain in turn by a series of deposits correlated with the Columbia formation of the east. The pebbles here are distinctive, those of Malvern in particular consisting chiefly of rounded and subangular fragments of novaculite.

A significant feature of the Appomattox formation in the Mississippi embayment is the enormous aggregate volume of gravel. East of the Mississippi the pebbles composing this gravel are commonly subangular or rounded fragments of chert, largely derived from the Sub-Carboniferous of the interior basin but partly from the Silurian and other strata. The distribution of this gravel, as well as the distribution of the formation in general, indicates that during the period of deposition of the formation the Tennessee river embouched directly into the Mississippi embayment of that period not far from what is now the northeastern corner of Mississippi. Another significant yet somewhat puzzling feature of the formation in its northern portion is found in the great beds of fine-textured and often snow-white silicious clay intercalated in the middle member and in the flecks and streaks of like material found throughout the loam of the upper member. It would seem possible, if not probable, that the greater part of this distinctive material consists of disintegrated chert, which was conveyed into the slack-water estuary anterior to the transportation of the non-decomposed chert by the stronger currents attending the close of the Appomattox period; so that the resemblance of the white markings to those in the eastern extension of the formation appears partly fortuitous. Still another significant feature of the formation is the accumulation of plant remains within it in northern Mississippi and western Tennessee and Kentucky. The fossils collected during the present season have not yet been studied, but the specimens collected by Safford and Loughridge have been examined by Lesquereux and Ward. It should be observed, however, that the age indicated by the few fossils thus far identified is hardly consistent with the voluminous evidence of stratigraphic position.

The known geographic distribution of the formation has been materially extended by the season's work. Originally it overspread the entire state of Mississippi, save a

beds of sands"—the upper member of the foregoing paragraphs), and referred the deposits doubtfully to the later Tertiary, though "strongly inclined to believe * * * that they are the lowest of the Quaternary stratified drift;"* while Safford, in a quite recent publication, apparently still further modifies the definition of the La Grange and refers it to the highest part of the Tennessee Tertiary, and moreover applies the term "Orange Sand" to a superficial formation assigned to the Quaternary,† probably the "Bluff Gravel" of the 1869 report.‡ Under the law of priority it would seem just to restore one of the early designations. But there are certain adverse considerations of sufficient weight to merit statement: (1) The definition of the "Orange Sand" has never been clear; it was originally applied by Safford to a certain series of deposits, was subsequently applied by Hilgard to a series different as a whole though identical as to one member, was still later reäpplied by Safford to a distinct deposit, and has been used in a lax and irregular manner by other geologists. (2) In no case does the definition of the "Orange Sand" by geologists who have used the term correspond with that of the Appomattox formation; for Safford's original "Orange Sand" included one of the older formations, while his later "Orange Sand" is a wholly post-Appomattox deposit; Hilgard included under the term not only the deposits now set apart, but also the newer gravels intercalated between the loess (or loam) and Port Hudson—the Bluff Gravel of Safford—as well as various older gravels of which a part are now assigned to the Potomac (Tuscaloosa) formation; and other users of the term have employed it in equally discrepant ways. (3) The name "Orange Sand" appears to have been originally applied, and certainly has been commonly used, rather as a descriptive term than a specific appellation; and, moreover, it is by many geologists considered desirable to employ only connotative formation names in which the principal element is geographic and indicative of the locality of typical development. (4) While the definition of the "La Grange" as given by Safford in 1869 agrees with that of the Appomattox, the deposits were adjudged Eocene instead of late Pliocene, as indicated by stratigraphic position. (5) Although the locality from which the La Grange was originally named was at that time a flourishing city, it has since, in consequence of war, the building of railroads and other vicissitudes, shrunk to a small village, with an uncertain tenure of life beyond the present decade.

This question of nomenclature would appear to be one upon which the Geological Society of America might well pass, and it is raised in the hope that it may be freely discussed and, if practicable, definitively settled by this representative body of American geologists.

The paper was discussed by J. M. Safford, C. H. Hitchcock, E. W. Claypole and W J McGee.

This paper was followed by a brief communication on—

THE REDONDA PHOSPHATE.

BY C. H. HITCHCOCK.

Redonda, a volcanic island situated between Nevis and Montserrat, lat. 16° 55′ N., long. 62° 13′ W., is one of the Leeward islands of the Caribbean sea. It is one

* Geological Survey of Kentucky: Report on Jackson Purchase Region, 1888, pp. 7, 52.
† Agricultural and Geological Map of Tennessee issued by the Commissioner of Agriculture, etc. (J. M. Safford, State geologist), 1888.
‡ Geology of Tennessee, 1869, p. 432.

[illegible]

[illegible] The [illegible] grade of [illegible] per cent. of phosphoric acid. [illegible]

[illegible] Antigua and many of the small islands of Central America. [illegible] that they were originally [illegible] If the mineral [illegible] the absorption of the [illegible] to con[illegible] But the nearly complete absence [illegible] problematical.

[illegible] occurrences of this redondite are known. May it not [illegible] through a bed of the lime phosphate, [illegible] the lime? Is it possible that the [illegible] the lava in a gaseous condition? The scarcity of [illegible] in small volcanic islands makes some such [illegible]

[illegible] There is one known phosphuret—Schreiber[illegible] beyond the earth's atmosphere in the absence of [illegible] but if a similar compound were brought to [illegible] it would soon become a hydrous phosphate. The [illegible] from meteoric masses is well known in the [illegible] generally conceded that it has originated in the earth and [illegible] Why may not this redondite have come up from

into one another. This would also agree with its extremely irregular shape. Such local subsidences are in harmony with what we know has occurred. If the channel of Mozambique between Africa and Madagascar has sunk 1,000 fathoms since middle Tertiary days, apparently without affecting the adjoining land to any great extent (and many similar cases could be quoted), there is nothing contrary to probability in believing that the same thing has happened elsewhere and repeatedly, or in regarding the oceans as the result of many such changes rather than as aboriginal features of the earth's surface.

AKRON, OHIO, *August* 15, 1890.

The paper was discussed by C. H. Hitchcock, J. J. Stevenson and E. W. Claypole.

The next paper was entitled—

THE CUYAHOGA SHALE AND THE PROBLEM OF THE OHIO WAVERLY.

BY C. L. HERRICK.

The paper was discussed by H. S. Williams, E. W. Claypole, I. C. White, A. S. Tiffany and C. L. Herrick. It is published elsewhere in this volume.

The next communication was on—

THE TACONIC ORES OF MINNESOTA AND OF WESTERN NEW ENGLAND.

BY N. H. WINCHELL AND H. V. WINCHELL.

The communication was discussed by C. H. Hitchcock and N. H. Winchell. It is printed in full in the American Geologist, vol. vi, 1890, pp. 263–274.

This paper was followed by—

WHAT IS THE CARBONIFEROUS SYSTEM?

BY H. S. WILLIAMS.

(*Abstract.*)

The confusion which arises from a lack of precise definition as to the constitution and limitation of the Carboniferous system has led to the preparation of this paper.

The earliest English author who appreciated the importance of grouping certain rock formations with the Coal Measures to form what now is called a system was W. D. Conybeare.* The German geologist Werner and the school of geologists that followed him called the Coal Measures the "Independent Coal formation" or "Steinkohlengebirge." Conybeare subdivided the "Transition and Secondary formations"

* Conybeare and Phillips, Outlines of the Geology of England and Wales. London, 1822.

The paper was discussed by W. [illegible], R. V. [illegible], C. L. Herrick, [illegible] Winchell and H. S. Williams.

The Society then adjourned until [illegible] p. m.

After reassembling in the evening the Society listened to—

THE [illegible] AND [illegible] GEOLOGY OF WESTERN [illegible]

BY ARTHUR WINSLOW.

The memoir was discussed by I. C. White, [illegible] Branner and W J McGee. It is published elsewhere in this volume.

In the absence of the author the following paper was then read by Mr W J McGee:

THE [illegible]

BY LAWRENCE C. JOHNSON.

The [illegible] plantation is about two miles above [illegible] station, on the [illegible] railway, and the landing of the same name on the Mississippi river. It is opposite the mouth of Bland bayou, a sluggish affluent of [illegible] river, which joins it [illegible] Lake Maurepas after it [illegible] the back swamps of this region. [illegible] The sluggishness of current in Bland bayou and neighboring water-ways should be borne in mind in estimating the length of time before the back swamps were filled up and the water reached to the front, despite the extraordinary force of the current [illegible] at the [illegible] crevasse. The first break began March [illegible], but it was not until March [illegible], nine days after, that the water came through the south pass of [illegible], the bayou or strait connecting Lake Maurepas with Lake Pontchartrain, and ten weeks more passed before Lake Maurepas overflowed the [illegible] sufficiently to threaten the track of the Illinois Central railway, and it was not until [illegible], or a month after the break, that the railway was [illegible] the running of trains. The water [illegible] from the [illegible] of [illegible] June [illegible]. The greatest height [illegible] feet above [illegible] Maurepas.

[illegible] that the banks of the [illegible] of the bayous and of [illegible] Maurepas, Pontchartrain and [illegible] are higher than the back swamps [illegible] and that the Mississippi river at the [illegible] crevasse [illegible] above the swamps about Lake Maurepas. It is [illegible] Central railway the highest ground [illegible] it was not suspected that the lowest ground [illegible] Maurepas, nor yet the quaking bogs to the south of it, [illegible] or prairies to the north, between [illegible] and Pontchartrain.*

* [illegible] the courtesy of Captain Mann, superintendent of the Illinois [illegible] as well as many facts connected with the [illegible]

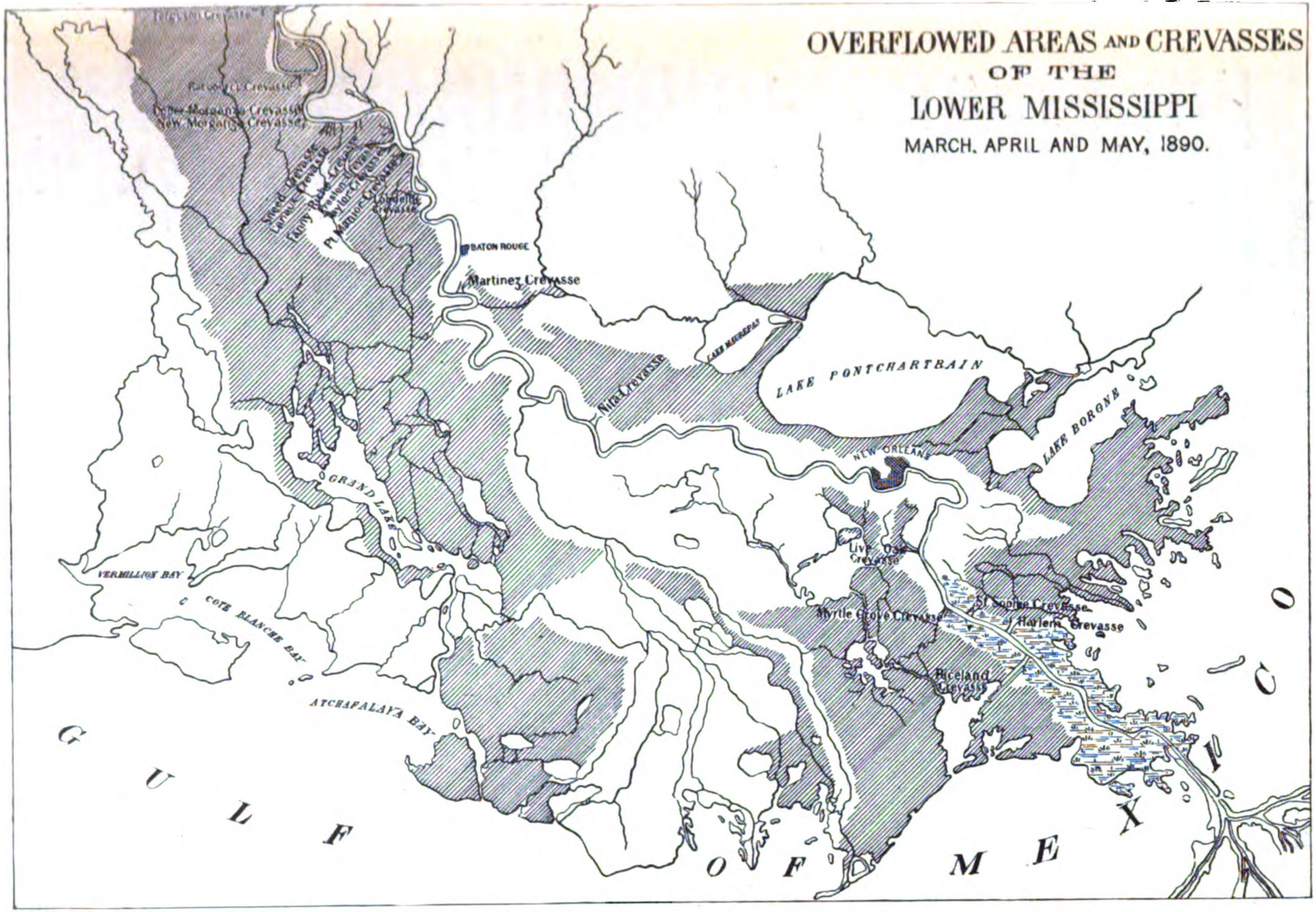
OVERFLOWED AREAS AND CREVASSES
OF THE
LOWER MISSISSIPPI
MARCH, APRIL AND MAY, 1890.
BATON ROUGE
Martinez Crevasse
Nita Crevasse
LAKE MAUREPAS
LAKE PONTCHARTRAIN
LAKE BORGNE
NEW ORLEANS
Live Oak Crevasse
Myrtle Grove Crevasse
St Sophie Crevasse
Harlem Crevasse
Riceland Crevasse
GRAND LAKE
VERMILLION BAY
COTE BLANCHE BAY
ATCHAFALAYA BAY
GULF OF MEXICO

Figure 1.

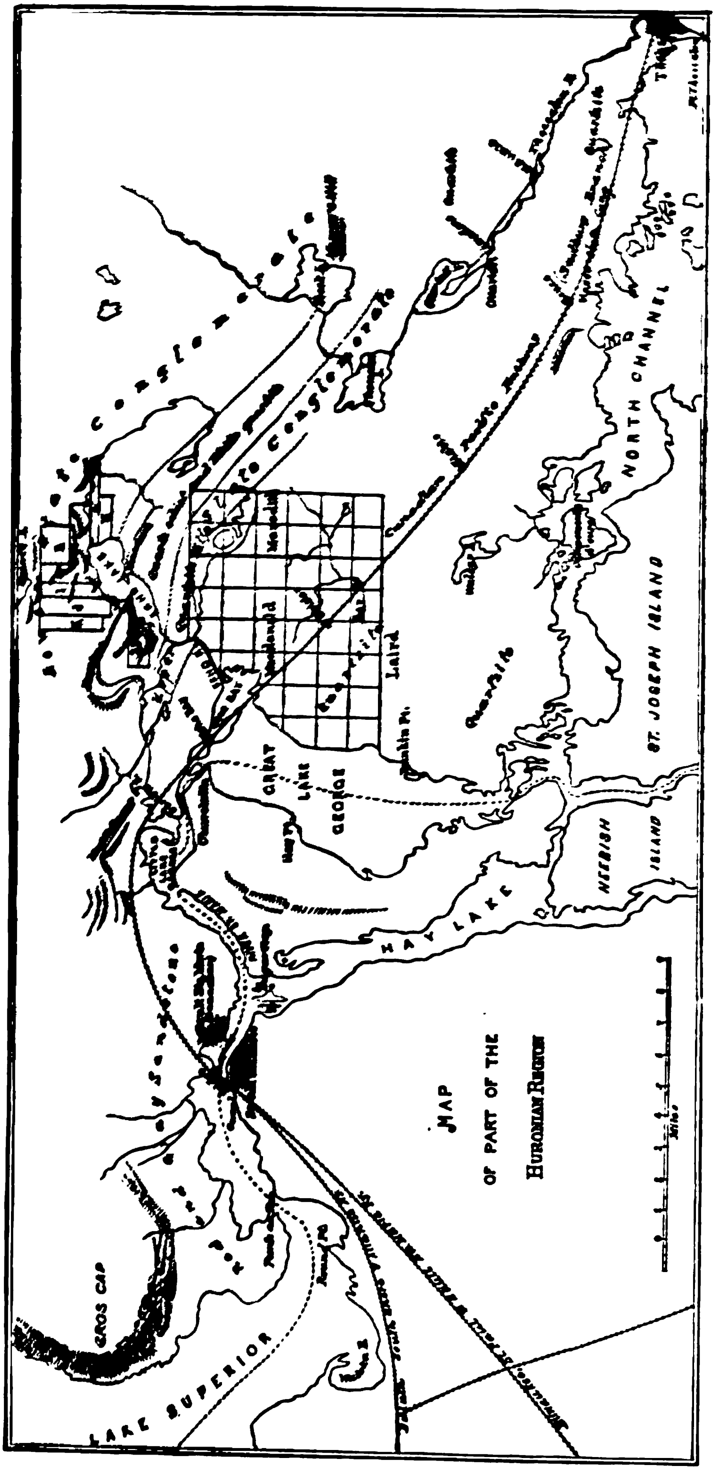
MAP
OF PART OF THE
HURONIAN REGION
Miles
LAKE SUPERIOR
GROS CAP
HAY LAKE
NEEBISH
ISLAND
ST. JOSEPH ISLAND
NORTH CHANNEL
GREAT
LAKE
GEORGE
Laird

FIGURE 1.

9. Greenstone	700 ft.
8. Whitish or whitish gray quartzite passing into quartzose conglomerate with blood-red jasper pebbles	1,000
7. Dark-blue and blackish fine-grained slates with dark-gray quartzite	500
6. Slate conglomerate	800
5. Limestone	250
4. Slate conglomerate	1,000
3. Greenish, silicious slates, unstratified, with pale greenish quartzite	1,200
2. Greenstone	400
1. Green, altered slates of a chloritic character	1,000

Mr. Murray recognizes the two slate conglomerates as separated by the limestome, but his language would lead us to suppose them not separated by any considerable amount of other strata; and he may have overlooked or underestimated such intervening strata under the impression, which he brought from Thessalon valley, that the two slate conglomerates were one formation. He says:

"Both above and below the limestone the rock is a slate conglomerate, the base of which is usually of a greenish color, frequently having the aspect of an igneous rock; but it contains numerous rounded pebbles of various kinds, the chief part of which are syenite, quartz, gneiss and jasper. In some cases the conglomerate is very coarse, the pebbles or bowlders, as they may be called, forming the greater part of the mass. In other cases the rock is a fine compact slate, inclosing rounded masses of various sizes and characters, which are scattered through the slate at wide distances from one another."

"The rocks beneath the lower slate conglomerate are greenish silicious slate and pale-green quartzite. * * * These are underlaid by greenstone, and below the greenstone is a highly altered green chloritic slate, which is exposed in nearly vertical strata, forming high precipices at the extreme head of the lake.*

The limestone between the two conglomerates is set down, meantime, as having an "average inclination of about 25°" (p. 21).

Mr. Murray speaks of tracing the two conglomerates on their strike south-eastward for a distance of about six miles, and says it is probable that the intervening limestone "holds the same course until it strikes the Thessalon and Ottertail lakes, on the Thessalon river, where it is already known to be exposed." But he nowhere gives a description of either slate conglomerate by itself.

The Succession on Echo Lake.—Now, let us consider carefully the stratigraphical succession seen along the shores of Echo lake. The upper slate conglomerate lies beneath the low ground which extends for about three miles to the foot of the lake. It is here succeeded (underlain) by a quartzite of a different character from the quartzites above the conglomerate, being, in its lower part, greenish or blackish and slaty. It passes thus from a

* Geology of Canada, 1863, pp. 22, 23.

one mile north of which it becomes the site of a marble quarry, yielding a delicate and beautiful product. Toward the southeast it has been traced for nearly six miles; but its continuity with limestones seen in the valley of the Thessalon is a question which will be taken up after completing a description of the section exposed along Echo lake and northward.

The breadth of the limestone outcrop is about 400 feet, if we take the mean of the points on opposite sides of the lake. Immediately north a hill

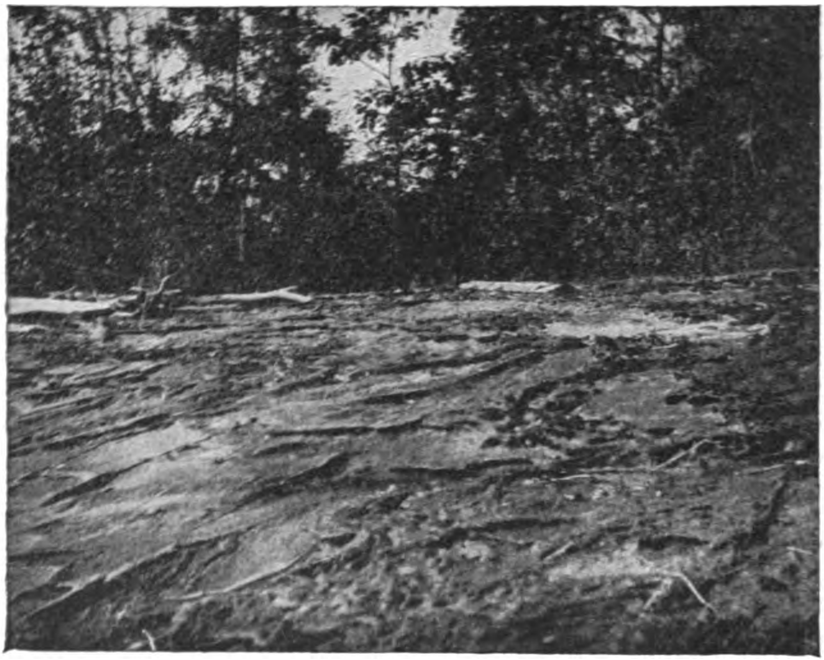

FIGURE 3.—*View of rough Surface of Echo Lake Limestone.*

(number 5) rises on the western shore about 100 feet, and the rock exposures present every appearance of a quartzose character; but the hill was not ascended. In close contiguity is another (number 6), which examination showed to be essentially quartzitic and finely granular, with minute disseminated individuals appearing like reddish orthoclase, but which in thin section prove under the microscope to be, in part, specks of iron peroxide. This formation is very thick-bedded, and dips about 20° toward south 40° west. Thus it appears that though the limestone is between two slate conglomerates it is separated from the upper by 2,700 feet, and from the lower by 900 feet. In other words, the slate conglomerates are here at least 3,700 feet apart.

Beyond this for the space of one-third to one-half a mile the high hills (number 7) were not examined, but still north for the distance of one and a

lake. This vicinity is appropriated, on Logan's map, to the *upper* slate conglomerate; but, as we have shown, the upper slate conglomerate terminates three miles south and is followed by felsites and felsitic quartzites, and this is, therefore, the *lower* slate conglomerate. Logan has located a "supposed outcrop of limestone" to the north of this, and has connected it with the Echo lake limestone toward the west, and extended it as far as Wahbiquekobing lake on the east; and then, by the manipulation of supposed faults in the valley of the Thessalon, has caused the limestone to reäppear nearer the coast and pass into the observed position of a limestone back of the Bruce mines. The Bruce limestone should then be identifiable with the Echo lake limestone—a question which we shall presently examine. In the intervening distance between these two branches of the limestone belt designated "3*e*," Sir William locates the similar branches of a calcareous formation designated "3*k*, Yellow chert and limestone." This is represented as coming between two quartzites, as "3*e*" is put down between two slate conglomerates. The whole geologic structure is worked out with consummate ingenuity on the assumption of faults in such places as would be necessary to produce the results depicted on the map. That a synclinal exists along the Thessalon valley it is easy to admit after an examination of the complementary dips. That the assumption of faults would afford easy explanations of phenomena as identified and understood by Logan will not be disputed. But to us who have studied a considerable part of the field, the numerous Logan faults appear a heavy tax on credulity and introduce what appears an artificial complexity in the geology of the region. It is admitted, however, that one or more faults probably exist—possibly all those laid down on the map.

Now, it was the opinion of Mr. Murray that the Echo lake limestone trends more to the southeast than Logan has represented, and makes connection with the limestone of Ottertail lake and Thessalon river, and, by means of a flexure, with the Bruce limestone also. Our petrographic examinations show that Murray was probably correct.

Microscopic Characters of Echo Lake Rocks.—Thin sections of the limestone from the western side of Echo lake (XXVI, 11 and 12) * show it to consist of very fine rounded grains of calcite, mostly quite refractive and showing extinctions on rotation. The grains are closely compacted, with very little interstitial matter. The dark linear bands are composed of matter of decomposition; apparently an argillaceous residuum after the solution of the calcareous matter of some portion of the original material. The rock contains occasional minute grains of quartz. This limestone is evidently fragmental, formed of grains of an older crystalline mass; at least of crystal fragments

* Our examples of these limestones are registered as follows, the numbers in parentheses referring to thin sections: Ansonia, 409 (IX, 6), 410 (IX, 7), 449 (XII, 11), 450 (XII, 12), 452 (XII, 14; Ottertail, 438 (XII, 6), 439 (XII, 7); Bruce, 388 (VII. 6); Echo lake, west side, 1092 (XXVI, 11), 1093 (XXVI, 12), 1095 (XXVI, 13), 1107 (XXVI, 16); Echo lake, east side, 1096 (XXVI, —); Garden river, 1108 (XXVI, 14).

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THE NICKEL AND COPPER DEPOSITS OF SUDBURY DISTRICT, CANADA.

BY ROBERT BELL, B. A. SC., M. D., LL. D., ASSISTANT DIRECTOR OF THE GEOLOGICAL SURVEY OF CANADA.

With an Appendix on

THE SILICIFIED GLASS-BRECCIA OF VERMILION RIVER, SUDBURY DISTRICT.

BY GEORGE H. WILLIAMS.

(*Read before the Society December* 31, 1890.)

CONTENTS.

INTRODUCTION.

The town of Sudbury, a creation of the Canadian Pacific railway, is situated in the backwoods of Ontario, thirty-six miles north of the mouth of French river, on Lake Huron. Parts of the surrounding country are tolerably level, but in a general way this region may be said to be hilly. Some sections are very broken and rugged, while in others rocky ridges alternate with swamps or alluvial intervals. Occasional tracts of land are fit for cultivation, but, as a rule, where the surface does not consist of rock or swamp it is much encumbered with bowlders. At one time the district supported large quantities of white-pine timber, but forest fires at different periods have destroyed the greater part of it and inferior kinds of wood are now growing

the same temperature, they would naturally accompany each other when in the fluid condition. The bodies of molten diorite, being large, would remain fluid for a sufficient time to allow the diffused sulphuretted metals to gather themselves together at certain centers by their mutual attractions and by concretionary action. In the case of great irrupted masses of diorite, the bodies of ore which had formed near enough to the solid walls cooled and lodged with a mixture of the broken wall-rocks where we now find them, while larger quantities, remaining fluid, probably sank slowly back through the liquid diorite to unknown depths. The causes which, at a subsequent time, favored the production of transverse dikes probably aided in determining the deposition of the ore near certain lines rather than elsewhere.

If we suppose that the molten sulphides abstracted themselves, by the laws of mutual attraction, from the general mass of the fluid rock and got together in considerable quantities in an intimately mingled form, the two kinds would tend by the same laws to separate themselves from one another, like going to like, just as salts of different kinds will separate into their respective crystals from an aqueous solution, because there is analogous action between mixtures liquefied by heat and by solution in a supersaturated menstruum. A study of the relations of the pyrrhotite and chalcopyrite to each other in these mixed ores and of the ores of the parent rock shows that this view is in accordance with the facts, and that it is probably a satisfactory explanation of the phenomena. No theory of aqueous deposition appears to account for the facts in connection with these ore bodies; still we do occasionally observe limited local modifications of the ore which may have been due to the solvent action of water with subsequent precipitation of mineral matters long after the consolidation of the mass. This is more particularly the case with regard to the chalcopyrite. Crystals of quartz and of the felspars and rarely of apatite are found embedded in the ore.

Extent and Associations of the Ores.

Other metals, including gold, platinum, tin, lead, silver, zinc and iron, have been found in the Sudbury district, and probably some of them may prove to exist there in paying quantities. The presence of a considerable proportion of nickel in the ore of the Wallace mine, on the shore of Lake Huron and in the strike of the Sudbury deposits, was ascertained by Dr. Hunt more than forty years ago; yet the presence of this metal in the latter does not seem to have been suspected for a considerable time after they had been worked for copper alone. The Huronian is notably a copper-bearing system. West of Sudbury, in the great belt we have already traced, this metal occurs around Batchawana bay, north of Sault Ste. Marie, at Little Lake George and Echo lake, at Huron Copper bay, in Wellington and Bruce mines,

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THE OVERTHRUST FAULTS OF THE SOUTHERN APPALACHIANS.

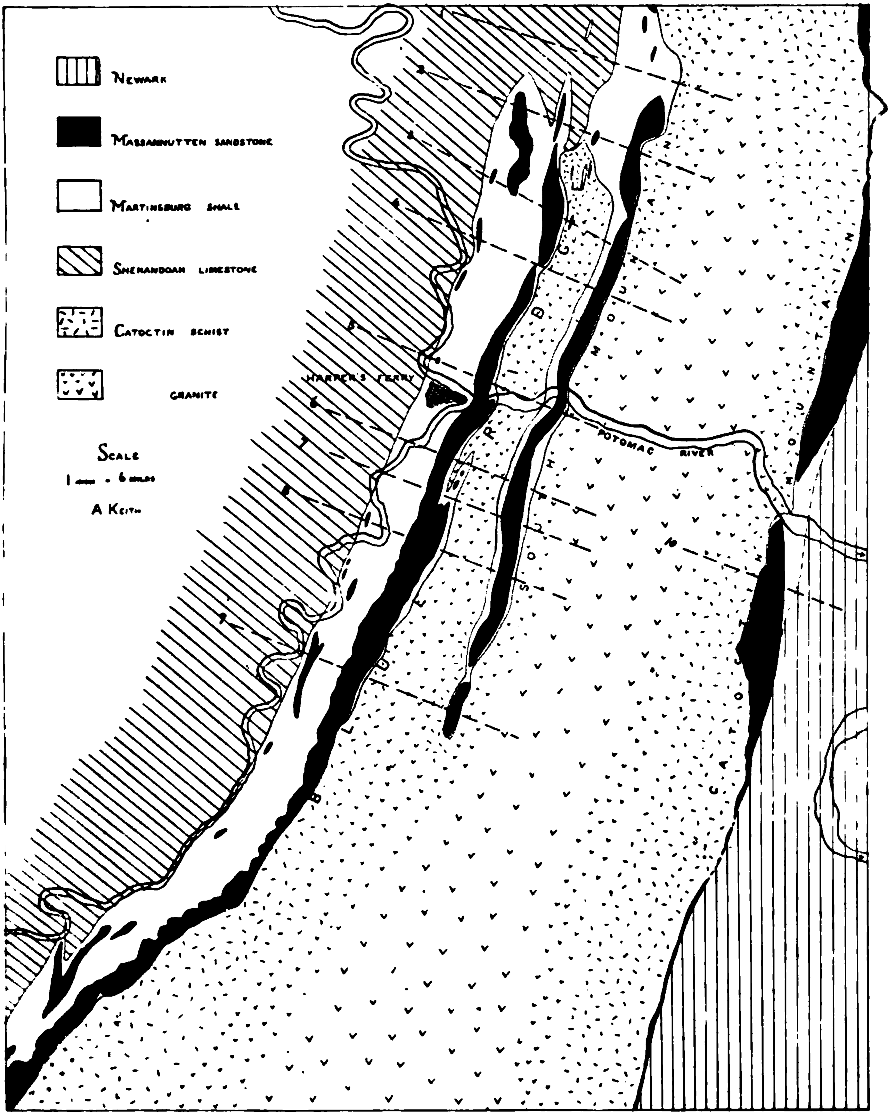
(*Read before the Society December* 29, 1890.)

BY C. WILLARD HAYES.

CONTENTS.

INTRODUCTION.

Through the work of the Rogers brothers in Pennsylvania and Virginia and of Safford in Tennessee, the characteristic forms of Appalachian structure have long been familiar to geologists. The *unsymmetrical fold* has been recognized as the normal structural form through Pennsylvania, Maryland, and a portion of Virginia. In east Tennessee, the *reversed fault*, transverse



GEOLOGIC MAP OF HARPER'S FERRY REGION.

have embraced a view so at variance with these facts. It is due to them to say that not all the facts are against them. In various portions of the Blue ridge there are sandstones dipping northwestward or toward the valley limestone, and the facts are susceptible of the interpretation that the sandstones are beneath the limestone. The section at Balcony Falls appears to show an *underlying* sandstone. One unequivocal case of underlying sandstone has been found by Darton five miles east of Dublin, where a visible anticline of sandstone lies under an extensive arch of valley limestone. Without doubt other cases will be demonstrated by closer study, and doubtful cases are already known.

Existence of two Sandstones.—It seems from the foregoing facts that there are *two* sandstones, one above and one below the valley limestone. There is nothing unusual about such an arrangement; among the fossiliferous series it is very common. Three or four times in the vertical column the same lithologic character recurs; but this simply indicates a renewal of similar conditions of sedimentation and has no bearing on age. There is no reason to suppose that these conditions did not exist before the limestone was deposited. Among the fossiliferous rocks the fossils enforce a discrimination of the sandstones; in the Blue ridge they do not. In their absence nothing but structural evidence can discriminate, and that, in the case of Rogers at least, was forbidden by the amount of ground to be covered. The mistake was made of correlating distinct and distant sections with insufficient connection by areas. It was, apparently, enough that they contained a group of rocks similar in texture and lay in the same topographic belt. In other words, instead of structure, lithology was made the basis of correlation, in spite of its unreliability in adjacent areas.

Certain cross-sections were taken as typical, and from them a stratigraphy was deduced. Into this mold the other observations were poured with the inevitable result that some of them, to put it mildly, lost their original character. Rogers' published sections of the Blue ridge at Harper's Ferry and Ashby's gap are distinctly wrong. In the former the limestone does not dip northwestward and the shale under it, as represented; nor does any sandstone bed reach water level until the main ridge is reached; nor is the sandstone-shale series a simple monoclinal sequence, but a highly contorted synclinal depression. His section a little south of Harper's Ferry gives the open syncline of Blue ridge as it is, but adds thereto a series of vertical sandstones that have no existence whatever. In his section at Ashby's gap, at the southwestern corner of the region under discussion, a synclinal ridge-cap is turned into a monoclinal bed; the low southeastward dips on the main ridge are shown, but the equally plain northwestward dips are not.

Rogers' sections show that he appreciated the want of harmony of his different observations and the difficulty of reconciling them. In view of the ob-

shales and Oswego and Medina sandstones. Along the western side of the Green mountains and southward through New York and New Jersey we have Cambrian sandstone and Lower Silurian limestone and shale in successive order, while in the Blue ridge section, described by Messrs. Geiger and Keith, the succession is, limestone, shale, sandstone, as in the Silurian section of New York just mentioned. In the latter case erosion has evidently not cut through the Silurian limestone to the Cambrian; and the section is that of an overlapping deposit upon a sloping pre-Paleozoic shore-line, similar to that about the Adirondack region. From these facts I think it probable that the interpretation of Messrs. Geiger and Keith is the correct one.

Professor C. H. HITCHCOCK: If the authors allow that the reference of the quartzites next the crystallines to the middle Silurian applies only to the region of Harper's Ferry, they may be correct. I understood them, however, to claim the reference of the whole of W. B. Rogers' number 1 to this horizon, insisting that no reliance should be placed upon the sections at Balcony Falls and near Christiansburg, where the sandstones or quartzites underlie the lower Silurian limestones. I am familiar with this part of the great valley of Virginia, and should interpret the structure as Rogers and Campbell have done, both by reason of the stratigraphy, and because fragments of the crystalline rocks further east are constituents of the basal conglomerates, which in their turn underlie the limestones. The presence of fragments of the older rocks in the derived sediments affords a better criterion for the determination of the succession of the terranes on the western flank of the Blue ridge than their dips. One can explain the presence of eastern dips by inversions or faults if necessary, but cannot understand how a composite sediment can be older than its constituent rounded pebbles. Thirty years since our best geologists overlooked this obvious principle in explaining the structure of these same rocks in western New England and referred the quartzites to the Medina; to-day there is not a single geologist familiar with the ground who would accept the early views of Logan, Hall and Dana in reference to this point. Hence these Harper's Ferry outcrops must represent only local dispositions.

Major JED HOTCHKISS: Can the authors of the communication inform us concerning the age and relations of the limestones frequently found east of the Blue ridge?

Mr. KEITH: Limestones sometimes occur as small lenses in slate over the Archean area east of the Silurian limestones of the Shenandoah valley. In one case (near Sharpsburg) the Silurian limestones rest on shales which may be Cambrian.

under the most favorable circumstances, long and careful research. In addition to the difficulties of structure to be expected in any great mountain system, special difficulties are found in the degree to which regional metamorphism has been carried, in the occurrence of great volumes of contemporaneous volcanic material at various stages, and (partly no doubt as a consequence of the last) in the extreme paucity of fossil remains. Still further, the circumstance that the region as a whole must be described as more or less densely wooded, contrasts it very unfavorably, from a geologist's point of view, with the southern and open parts of the Cordillera, where he who runs may read many of the main structural facts.

Up to the present time the horizons which have in British Columbia been actually fixed by paleontological evidence may be summarized as follows:

1. Tertiary (probably Miocene).
2. Cretaceous (various stages, probably extending from the Laramie as far down as the Neocomian).
3. Alpine Trias.
4. Carboniferous.
5. Silurian (*Halysites* beds).
6. Cambro-Silurian (Trenton-Utica and perhaps somewhat lower).
7. Middle Cambrian.
8. Lower Cambrian (*Olenellus* beds).

Of these horizons, all but the Miocene have been recognized in the Rocky Mountains proper, or eastern range of the Cordillera. On the coast no fossils definitely older than the Carboniferous have yet been detected. In the interior plateau, fossils referable to the Miocene, lower Cretaceous, Alpine Trias and Carboniferous have been rather sparingly found, while in the mountain region of the Gold system, including the Selkirk, Purcell, Columbia and other ranges, we are as yet almost entirely without paleontological evidence.

Surveys in the Interior Plateau Region.—The writer has been engaged for some time in a detailed examination of an area of about 6,400 square miles in the interior plateau region, the materials for a geological map of which have now been obtained and are in course of elaboration. In connection with this work, and more particularly to assist in explaining the complexities of the older rocks of this area, it became desirable to ascertain, so far as possible, the relations of these rocks to those of the Rocky Mountains proper, across which one line of section has already been carefully worked out by Mr. R. G. McConnell.

With this object in view a preliminary examination was made last autumn across the intervening Selkirk range, on the line of the Canadian Pacific railway. This examination was necessarily confined to the vicinity of the railway and still requires to be supplemented by much detail, to be obtained

Provisional Comparative Table of Formations met with (1) *in the eastern Border of the Interior Plateau of British Columbia,* (2) *in the Selkirk Range, and* (3) *on the western Side of the adjacent Portion of the Rocky Mountain Ranges.*

	1. Section on Kootanie and Adams lakes.	Feet.		2. Section in the Selkirk range on line of Canadian Pacific railway.	Feet.		3. Section in the Rocky Mountains (west side of range; McConnell).	Feet.	
	6. Greenish and gray schists, with limestone	2,000		Quartzites with gray schists and some limestone.			*Halysites* beds. Dolomites and quartzites	1,800 or more.	CAMBRO-SILURIAN AND SILURIAN.
	5. Limestone or marble, with black, glossy argillites and some gray schists	2,500		Black shaly argillites, limestone and gray schists.			*Graptolite*-bearing shales. Black fissile argillites, with some limestone	1,500	
Adams Lake series.	4. Chiefly greenish, with some gray schists	4,050	*Selkirk series.*	Gray schists and gray quartzites, with some quartzose conglomerate and interbedded blackish argillites, the last chiefly toward the base	25,000	*Castle Mountain group.*	Greenish and gray calc-schists and greenish and reddish shales and slates, with some dolomitic limestone	10,000 (probably).	
	3. Chiefly gray, with some greenish schists	8,550							
Nisconlith series.	2. Black shaly or schistose argillite, with some limestone	1,000 or more.	*Nisconlith series.*	Blackish argillite-schists and phyllites, generally calcareous, with some beds of limestone and quartzite	15,000	*Bow River series.*	Dark argillites, with some quartzites and conglomerates, the latter particularly toward the summit. Base not seen	10,000 or more.	CAMBRIAN.
Shuswap series.	1. Mica-schists, gneisses and marbles	5,000 or more.	*Shuswap series.*	Gray gneissic rocks and coarse mica-schists	5,000 or more.				ARCHEAN.

resemblance of the formations to those met with in the Rocky Mountains is in itself sufficient to enable some important general conclusions to be arrived at respecting the rocks of the Selkirk range, while the analogy of the rocks of the Selkirks to those of the first section is also such as to afford some clue to the age of the formations represented in it.

The Shuswap Series.—The lowest crystalline, and presumably Archean, rocks largely represented in the western portion of this part of the Selkirk range are evidently referable to the Shuswap series of the first section. They consist chiefly of gray gneisses, varying from nearly massive to quite schistose, and in the latter case frequently having their division-planes thickly covered with glittering mica. They are both hornblendic and micaceous, but the last-named mineral usually preponderates. Orthoclase is apparently the most abundant feldspar, quartz is nearly always well represented and garnets are not infrequent. In many places nearly half the entire mass of the rocks exposed consists of intrusive or vein granite, with pegmatitic or graphitic tendencies.

The Nisconlith Series.—Overlying the basal holo-crystalline series in the Selkirk section is a mass of rocks of which the thickness is estimated at 15,000 feet. These are dark-colored and generally blackish argillite-schists and phyllites, representing various stages in alteration between true argillites and micaceous schists. The rocks are usually rather finely fissile, with glossy and sometimes wrinkled surfaces, but often with much minute yet visible mica on the division-planes. These planes are in some cases evidently due to cleavage, but are often true bedding-planes. The rocks are usually calcareous, and frequently hold thin layers of dark-bluish or black impure limestone, together with occasional layers of dark quartzite. The coloration is evidently due to carbonaceous matter, and pyrites crystals are very common in certain zones. The only notable diversity met with in this otherwise homogeneous mass of rocks is found towards the base, where (at the lower end of Albert cañon) a bed of pure blue-gray crystalline limestone thirty feet or more in thickness occurs, and a short distance still lower in the section, a series of beds over 1,000 feet in thickness, consisting chiefly of granular pale-gray quartzites. The quartzites are sometimes flaggy and generally more or less micaceous, and are interbedded as well as overlain and underlain by blackish micaceous argillites and layers of coarsely micaceous pale schists.

These rocks undoubtedly represent the Nisconlith series of the first column, of which no extended sections have yet been found in the interior plateau, while to the eastward they certainly correspond in the main with the Bow River series of the Rocky Mountains, for which a thickness of 10,000 feet was there ascertained, though the base of the series is never exposed in the Rocky Mountains.

River series of the Rocky Mountains are paralleled by similar conglomerates which abound in the upper series of the Selkirks. No unconformity has been observed between the upper and the lower masses of strata in either place.

Though in the Selkirk section the lower of the two great series which have been described resembles the Nisconlith of the interior plateau so closely as to warrant extending the same name to it, the fact that the overlying member of the section differs considerably from the Adams Lake series of the interior plateau, while on the other side it probably represents not only the whole Castle Mountain group but also the upper part of the Bow River series of the Rocky Mountains, renders necessary the application to it of a provisional distinctive name. It is therefore proposed to refer to this rock-mass as the *Selkirk Series.*

General Relations of the Cambrian.—Regarded as a whole, we find reason to believe that the Selkirk section exhibits a great Cambrian formation which (by analogy with the Rocky Mountains) includes the lower part of the Cambro-Silurian and reaches down from it to and far beneath a horizon at which the *Olenellus* or lower Cambrian fauna has been found, with an aggregate thickness of about 40,000 feet.

The comparatively pure limestones of which the Cambrian of the eastern part of the Rocky Mountains is composed are replaced in the western part of that range by rocks largely clastic in origin. This change in lithological character appears to continue and to become still more marked and to be accompanied by increasing thickness in the Selkirk range. Much of the clastic material is silicious, and the introduction of an increased proportion of such material may be explained by considering it as a result of approach to the shore line of Archean rocks on the west. While the principal development of contemporaneous volcanic products, whether in the Paleozoic, Mesozoic or Tertiary, is confined to a region west of the local Archean axis, the writer is inclined to believe that a portion of the remarkable difference found to occur in the western extension of the Cambrian may be due to the inclusion in its rocks, on this side, of volcanic ash deposits or other fine-grained volcanic materials, of which the composition was such as to favor the subsequent production of sericitic or sericite-like schists.

Speaking generally, the great Cambrian formation of the Rocky Mountain and Selkirk ranges shows many points of resemblance to the Cambrian and so-called "Algonkian" rocks of Utah and Nevada, the resemblance being particularly close in some respects to the series shown in the well-known Wasatch section, in which more or less distinctly micaceous schists are also found. It is, further, not at all unlike the Cambrian of Wales, which, though the organic remains are chiefly confined to some upper beds, has a thickness of 25,000 feet and is believed to exceed this in Shropshire.* The provisional

* Text Book of Geology; Geikie, 2nd edition, 1885, p. 651.

that the very thick Cretaceous formations never extended. It must further be borne in mind that the actual width of 100 miles measured across this folded and faulted region represents a zone of very probably double this width of the surface as it was antecedent to the great folding and faulting. In this zone the line of maximum sedimentation appears to have moved progressively eastward, or away from the local Archean land, in the later periods.

DISCUSSION.

Dr. J. W. Spencer: I desire to again* claim priority for the name Algonkian, on the ground that before its publication I had used the term "Algonquin" to designate an episode in the Quaternary history of the region of the Great Lakes.

Mr. G. K. Gilbert: While the two names referred to by Dr. Spencer are based on the same root, one has the adjective form and the other the nominal, and confusion is thus avoided. The simultaneous and unobjectionable use of nouns and adjectives etymologically identical for different elements of geologic classification is illustrated in the case of the "Huron shale" and the "Huronian system," and in that of "Erie clay" or "Erie shale" and the "Erian period" or system. The use of "Erie shale" for a Paleozoic formation conflicts with the use of "Erie clay" for a Pleistocene formation, but neither conflicts with Sir William Dawson's term "Erian."

*Cf. Bull. Geol. Soc. Am., vol. 1, 1889, p. 238, note.

antly narrow; in the underbrush of the plateau they wound about in such manner as to exaggerate the impression of distance. It was shrewdly calculated that any geologist by these means topographically misled might be geologically confused and led to count a single coal bed seen at different openings as several beds. And this calculation was justified by the result. An expert of high standing, whose experience and reputation fairly commanded confidence, reported the coal at nearly three times its actual thickness, and $750,000 was paid on his mistake. The error in stratigraphy followed from ignorance of the local geologic structure, both avoidable had the geologist determined relations of distance and direction among observed sections.

The point of this story is the point of this article: A knowledge of relations in space among geologic facts is essential to the solution of problems of stratigraphy and structure, and it follows that the geologist must locate his observations on a map either prepared in advance or surveyed simultaneously with his work. The possession of an adequate map constitutes the ideal initial condition for geologic work.

Definition of an adequate Map for Geologic Purposes.

General Definition.—An "adequate map" is one which accurately describes the character of the features delineated: it is so characteristically true to the facts of topography and culture that it offers many tie-points, *i. e.*, many points which can be definitely recognized as the representatives of specific locations on the ground. Such points are essential to the location of a geologist's observations of outcrops, strikes and dips, or formation boundaries, which may be of very limited extent but which must be placed on the map with such accuracy that the error, reduced to the scale of the map, is insignificant. Such tie-points are bends of roads, cross-roads, crossings of roads and streams, sharp turns in streams, stream junctions, springs, mountain peaks, ridges, gaps, spurs, abrupt changes of slope; in a word all characteristic features.

Maps are sketches fitted to a geometric control. If we compare them with works of higher art, we may liken the painfully exact military maps of Europe to miniature portraits, while some American maps, produced under demand for quantity rather than quality, suggest paintings executed with a palette knife. The difference lies in the minuteness of control, in the number of points accurately determined per square inch of map.

Methods of Control.—The measurements which constitute control are obtained by two methods, triangulation and meander, each of which has its advocates, each of which requires certain natural conditions for economic working, but which in most regions can advantageously be combined.

to the limited outlook in a Michigan forest, cannot well devise details of methods for him who studies stratigraphy and structure on the treeless plains of the west. Nor can he whose stratigraphic work in the settled states is facilitated by roads prescribe methods for the investigator of volcanic geology in uninhabited mountain ranges. Each must adapt to his own environment the means of recording and arranging observations, but he will certainly do so more intelligently if he avails himself of the experience of others, whose training and experiments may contain positive or negative suggestions.

Believing this, I propose to give here for what it is worth the experience of the Appalachian division of the United States Geological Survey with graphic methods of mapping formations.

Appalachian Work in the U. S. Geological Survey.—The Appalachian Paleozoic province presents stratigraphic and structural problems under an aspect which is familiar to all of us. Relief is seldom emphatic, heights have usually struck an average elevation through successive base-leveling, soil covering is the rule, vegetation flourishes everywhere, and cultivation assists in obscuring geologic facts: these are obstacles to rapid work, whatever the problem. On the other hand, relief and structure are intimately related as effect and cause, the factors of the problems, multitudinous as they often are, are crowded together in small space, every part of the region is easily accessible, roads and houses permit facilities not else available: these are aids to successful work.

The geologists of the United States survey who entered this province prior to 1886 were trained in western fields and did not at first devise the best methods of work. The amount of geology per square mile was embarrassing to them; the facilities afforded by culture were not appreciated. It seemed, moreover, a fair assumption that the Rogers brothers, Safford and others had solved the geologic problems of the region and that to resurvey their fields was but to confirm their results, which must be done in detail and with great accuracy. Triangulation for detail was forbidden by the absence of marked features of relief or culture, and meander methods were a necessity in the absence of adequate maps.

Stadia Transit Method.—The special conditions and the fact that the purpose of the work was section-measurement led to the selection of a very accurate method based on stadia measurements of distances. The instrument used was a light transit, mounted on tripod and leveling screws, carrying a telescope with a vertical limb and fixed stadia wires. The stadia rod was 12 feet long and graduated by experimenting with a base measured by a steel tape; there were two movable targets, which were adjusted by the rodman on signals from the surveyor until the interval between them was proportioned to the space between the stadia wires of the telescope; the

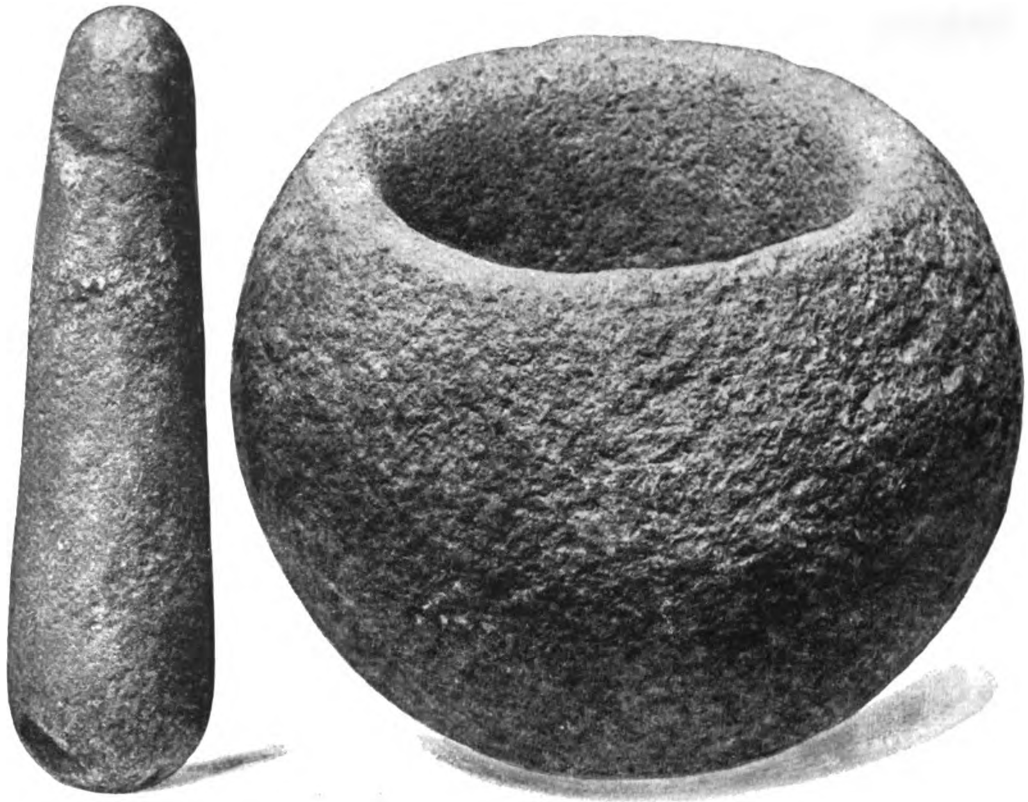
The traverse table was devised by Mr. Gannett for the purpose its name indicates. He describes it as follows:

"The plane-table used for traversing is of the simplest possible form, consisting of a board 15 inches square, into one edge of which is set a narrow box containing a compass needle three inches in length. The table is supported by a tripod of light construction without leveling apparatus, the level of the instrument being effected by the legs of the tripod. The table is adjusted in azimuth or oriented by means of the compass needle, movement in azimuth being provided by simply turning the table on top of the tripod head. There is no clamp to the azimuth movement, the table being held in place simply by friction. The alidade consists of a brass rule 12 inches long, with raised sights hinged to turn down when not in use. Ordinary drawing paper backed with cloth is used for plane-table sheets and is attached to the board by thumb tacks." *

The operation of traversing with this instrument is very simple. At each station the table is oriented by bringing the compass needle to a mark on its short scale; the area of the map is usually too small to show any convergence of magnetic meridians, and if the magnetic declination be constant it follows that at each station the position of the table is parallel to all those preceding it. Courses sighted and drawn with the alidade, whether successive foresights or alternating foresights and backsights, therefore depart from each other with angles equal to those included by the directions on the ground, and the lengths of the sights being laid off to scale, the plat is a figure mathematically similar to the traverse on the ground. On this plat geologic observations can at any instant be indicated in their proper relations. It is customary to foresight to bend of road, tree, fence-corner or any other distinct object, to wheel or pace to the thing sighted, thence to wheel or pace to a convenient station and set up the table. At this station the operations are: (1) to orient the table, (2) to scale off the first foresight, (3) to sight and draw the backsight and scale it off, (4) to sight and draw the next foresight, (5) to sketch in topography or geology, and then to proceed. Time is economized by occupying alternate stations only, and geologic relations are developed as fast as the traverse line is extended. I believe that this simple instrument will prove to be of great value to geologists and will save time, labor and money in the extensive work of geological mapping.

But notwithstanding the simplicity and accuracy of the traverse table, geologists who do not wish to carry a mounted instrument of any kind have tried to accomplish the same object with only hand compass and note-book. To do this is to reduce instrumental impedimenta to a minimum, but the observation and recording of the traverse requires more care than on the plane-table. Given an ordinary clinometer compass with square base and sights and a note-book ruled in squares, the operation at any station is as

* Unpublished MSS.



MORTAR AND PESTLE FROM AURIFEROUS GRAVELS, CALIFORNIA.

MOSS ENG. CO., N. Y.

The assertion that human remains or implements of any kind are found with such fossils is surprising enough to provoke skepticism; but when it must be added that the implements said to have been discovered in these deposits are most unquestionably neolithic, on a level so far as workmanship is concerned with those in use by the California Indians during the present century, and that the famous Calaveras skull is of no lower type than that of the living Indians of the northwest, it cannot be wondered that many European naturalists and some American authorities refuse to accept as genuine the discoveries announced.

If such an association of remains actually occurs, theories must be modified to fit the fact; but novel facts require evidence as strong as their apparent improbability is great.

I have come into possession of proofs of the occurrences in question which are in some respects more convincing than any yet brought forward. I propose to lay these before the Society and then to make a suggestion as to the method of reconciling these facts with those observed elsewhere.

Geology of Table Mountain.—The history of the Tuolumne Table mountain is briefly as follows: Long before glaciation began in the Sierra the Stanislaus river pursued a course nearly parallel to its present bed, but some three miles further southward. It filled a broad channel with coarse gravels which have since become compact and partially indurated. After these gravels had reached a thickness of some 200 feet there was an eruption of basalt which ran down the channel and covered it with an even-topped sheet of lava often 150 feet thick. The glaciation of the Sierra began after this flow, and seemingly soon after it. During the glacial period of California the Stanislaus, displaced from its former bed, cut a new and far deeper one, so that the river now runs a couple of thousand feet below the top of Table mountain. It must clearly have eroded this great depth since the lava flow, and the lava sheet remains as the cap of a relatively elevated mass.

The gravels of Table mountain have yielded and still yield much gold, and very numerous tunnels have been driven into the mass for the purpose of finding the precious metal. In the course of these explorations fossils, including mastodon remains, have certainly been found. It is also asserted that human relics have been discovered beneath the lava cap.

Instances of the Occurrence of Relics beneath the Lava Cap.

Relics recorded by Whitney.—The following is a brief résumé of the discoveries of human relics reported by Professor J. D. Whitney:* Dr. Perez Snell of Sonora picked from a car-load of gravel, as it was coming out from under Table mountain, a stone grinding implement which was examined by Professor Whitney. Dr. Snell also possessed many other implements and a

*Auriferous Gravels, 1880, p. 264.

At a distance of between 1,400 and 1,500 feet from the mouth of the tunnel, or of between 200 and 300 feet beyond the edge of the solid lava, Mr. Neale saw several spear-heads, of some dark rock and nearly one foot in length. On exploring further, he himself found a small mortar three or four inches in diameter and of irregular shape. This was discovered within a foot or two of the spear-heads. He then found a large, well-formed pestle, now the property of Dr. R. I. Bromley, and near by a large and very regular mortar, also at present the property of Dr. Bromley.

All of these relics were found the same afternoon, and were within a few feet of one another and close to the bed-rock, perhaps within one foot of it.

Mr. Neale declares it utterly impossible that these relics can have reached the position in which they were found excepting at the time the gravel was deposited, and before the lava cap formed. There was not the slightest trace of any disturbance of the mass or of any natural fissure into it by which access could have been obtained, either there or in the neighborhood.

And Mr. J. H. Neale declares upon his oath that the foregoing statement is in every respect true.

JOHN H. NEALE.

Subscribed and sworn to before me this second day of August, 1890.

EDWIN A. ROGERS,
Notary Public.

The larger mortar and the pestle referred to in this statement are illustrated in the accompanying plate 7, which is a photo-mechanical reproduction (by the Moss process) of a photograph of the objects, one-third natural size. The rock of which the mortar is made is andesite.

It would have been more satisfactory to me individually if I had myself dug out these implements, but I am unable to discover any reason why Mr. Neale's statement is not exactly as good evidence to the rest of the world as my own would be. He was as competent as I to detect any fissure from the surface or any ancient workings, which the miner recognizes instantly and dreads profoundly. Some one may possibly suggest that Mr. Neale's workmen "planted" the implements, but no one familiar with mining will entertain such a suggestion for a moment. No workman would dream of planting so large a number of implements, even to deceive a visitor, and he could conceal them only in broken ground. The auriferous gravel is hard picking, in large part it requires blasting, and even a very incompetent superintendent could not possibly be deceived in this way.

It has sometimes been objected to the authenticity of the discoveries of implements in the gravels that the finders, with the exception of Dr. H. H. Boyce, were miners and not scientific men. Now, so far as the detection of a fraud is concerned, a good miner regularly employed in superintending the workings would be much more competent than the average geological visitor. The superintendent sees day by day every foot of new ground exposed, and it is his business to become thoroughly acquainted with its character, while he is familiar with every device for "salting" a claim. The geological vis-

forced out of its place with considerable difficulty on account of the hardness of the gravel in which it was tightly wedged. It left behind a perfect cast of its shape in the matrix, and proved to be a part of a polished stone implement, no doubt a pestle. It seems to be made of a fine-grained diabase. This implement was presented to the Smithsonian Institution on January 20, 1870. It is shown in the accompanying cut (figure 1), a photo-engraving from a drawing by Mr. W. H. Holmes. Mr. King is perfectly sure that this implement was in place, and that it formed an original part of the gravels in which he found it.* It is difficult to imagine more satisfactory evidence than this of the occurrence of implements in the auriferous, preglacial, sub-basaltic gravels.

The Calaveras Skull.—As is well known, there is also evidence indicating the existence of human remains in the gravel beds, particularly that afforded by the famous Calaveras skull. This strange relic I shall not fully discuss on this occasion, but a few words concerning it will not be out of place. No one has doubted that Mr. Mattison found the skull in the auriferous gravels beneath the lava, 130 feet from the surface, and that he honestly supposed it to be in place; but it has been asserted that it was purposely concealed there by others. Now the chemical analysis of the bone shows that it is a fossil. It contains only a trace of organic matter, over 62 per cent. of calcium carbonate, and only about 34 per cent. of calcium phosphate. A rhinoceros jaw from the same horizon contained more than two and a half times as much phosphate as carbonate, and was thus much less completely fossilized than the human bone. Truly fossilized human bones are very great rarities, and to suppose that the miners were not only successful in "salting" the mine with human bones, but that they procured truly fossil bones to do it with, requires a painful stretch of the imagination. But, further, when the skull was found a mass of gravel indistinguishable from the surrounding material adhered firmly to it and remained thus attached until, long afterwards, Dr. Jeffries Wyman removed it in Cambridge, Massachusetts. Hence the miners must have found it, if at all, in a formation similar to or identical with the auriferous gravels. The supposed joke would therefore be quite without point.

It has also been suggested that the skull may have fallen from the surface through some crack in the rock at a time sufficiently remote to allow the fossilization and the induration of the surrounding mass to take place. There is no direct evidence in favor of this hypothesis, and it is highly improbable that an open cleft 130 feet deep could be formed by natural causes in a mass of gravel capped by only 40 feet of lava. The fact that part of the tibia of another human being, too small to have owned the skull, was found in the mass adhering to the larger bone makes the suggestion more difficult of

* I have submitted this statement of his discovery to Mr. King, who pronounces it correct.

Altogether, these circumstances seem strongly confirmatory of the genuineness of the object. Mrs. Darwin was a tourist on her way from the Yosemite, and evidently neither she nor Mr. McTarnahan had set any special importance upon the geological position in which the mortar was found. Mr. McTarnahan is a young man, about twenty-five, and had never heard of the discoveries reported by Dr. Snell in the Valentine shaft, and evidently had been totally unimpressed by the archæological discussions with reference to that region; so that the evidence seems to me of a very high order.

begins with disintegration and ends with the reduction of the rock to the most insoluble products, such as quartz, clay and ferric oxide. The depth of this decay, other things being equal, is determined by lapse of time, by the permeability of the rock, and by the solubility of its constituents, rather than by its hardness. In tropical countries, and in our southern mountains, this depth is to-day measurable in places by hundreds of feet. I showed that when, by change of climate, the protecting vegetation was destroyed and the disintegrated region became arid, this great decayed mantle became the prey of the winds, and thus furnished the material for the wind-blown loess. Where, on the other hand, such a region became the seat of a continental glacier, this decayed mantle supplied, in its finer material and in its cores of semi-disintegrated blocks, the source of the greater part of the glacial débris.

Since the limit of the decay in depth is due to the character of the rock areas, the removal of the mantle by wind or ice would leave a topography different from that formed by stream erosion, and one in which rock basins would be frequent.

Finally, the rapidity with which this material, after accumulating by wind or ice, is removable by erosion, or by progressive ocean breaching, rendering turbid the waters of formerly clear parts of the sea, suggests the cause for the extinction of life and change of coast faunas.

The views expressed in the paper referred to were accepted in their entirety by von Richthofen* and, as bearing on glacial débris, rock basins and the topography of Scandinavia, by Nathorst.†

Evidence of secular Disintegration in ancient Rocks.

Derivation of Cambrian basal Conglomerates.—Our work in the Green mountains, and recent studies of the mountains of western North Carolina, have given me proof that the recognition of the importance of secular disintegration is essential to a proper interpretation of some of the most difficult points in the study of the crystalline schists. Throughout the Green mountains and the Appalachians, the Cambrian conglomerates and quartzites, resting on an older crystalline complex, contain large quantities of detrital feldspar in fragments or pebbles, up to three-quarters of an inch and more in diameter, together with grains and pebbles of blue quartz, all clearly derived from the destruction of the older granitic rocks. These feldspars are the same as those in the older rocks, and show their own detrital character. They often show partial kaolinization around or adjoining an unaltered nucleus. And in some cases these fragments, as my assistant, Dr. Wolff, finds, have been

* China, Vol. II, 1882, p. 758.
† "Pumpelly's teori om betydelsen af herzartemas sekulära förwittring för uppkomsten af Sjöar m. m."—Geol. Föreningens i Stockholm Förhandl, 1879, No. 52, Bd. IV, No. 10.

limestone and sandstone, which incline at a lower angle (15° to 20°) away from the mountain mass.

Resting immediately on the altered porphyry is a bed, 10 to 15 feet thick, of angular fragments of ore, with the interstices filled with detritus of decomposed porphyry, which, showing no signs of stratification, follows the contact in depth. In places the limestone itself contains rounded pebbles of ore, but more of decomposed porphyry, forming in some beds a conglomerate. The residuary ore of the fragmental mantle-bed is evidently derived chiefly from a 30-foot vein of solid ore, which comes to the surface on the western flank and runs nearly parallel to the strike of the bed of fragmental ore. This bed is part of the pre-Silurian mantle of disintegration, and is not a Silurian sedimentary deposit. This is clear from the facts that it not only shows no stratification, but that the material filling the interstices between the ore fragments is wholly decomposed porphyry, without sand or limestone; whereas,

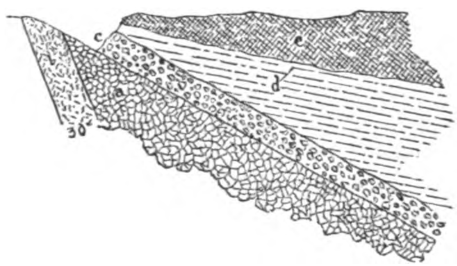


FIGURE 4.—*Section exposed by Mining on western Flank of Iron Mountain, Missouri, showing Mantle of pre-Silurian residuary Ore under Silurian Limestone.*

a = Decomposed porphyry; *b* = Vein of ore; *c* = Pre-Silurian mantle of residuary ore, 10 to 15 feet thick; *d* — Silurian limestone; *e* — Earth.

if it had been moved by breaching action, a separation would have taken place, resulting in the removal of the porphyry detritus and its replacement by sand and calcareous matter.

On the eastern flank, Professor Potter's explorations revealed a pre-Silurian valley, in which a large amount of detrital ore is accumulated, beneath the limestone. The mining has followed this valley for 1,500 feet or more, down its gentle slope, under the Silurian limestones and sandstones. Here also, while the overlying limestone carries more or less débris from the mountain, the ore-bed is unstratified and has its interstices filled with a wash of decomposed porphyry. The bed is in places 40 feet thick and 300 feet wide, growing narrower toward the lower end of the valley, and thinning out toward the sides, where the limestone rests directly on the porphyry. Toward the lower end of this ancient valley, the ore-blocks are larger and rather more rounded than those further up-stream. I imagine that these lower bowlders are the older ones and started from their source when the parent hill was

[illegible] In height these hills vary from low mounds [illegible] diminutive mountains, 400 or 500 feet above the [illegible]. As a rule, however, the height does not exceed 1200 feet, [illegible] in the neighborhood of 150 feet high.

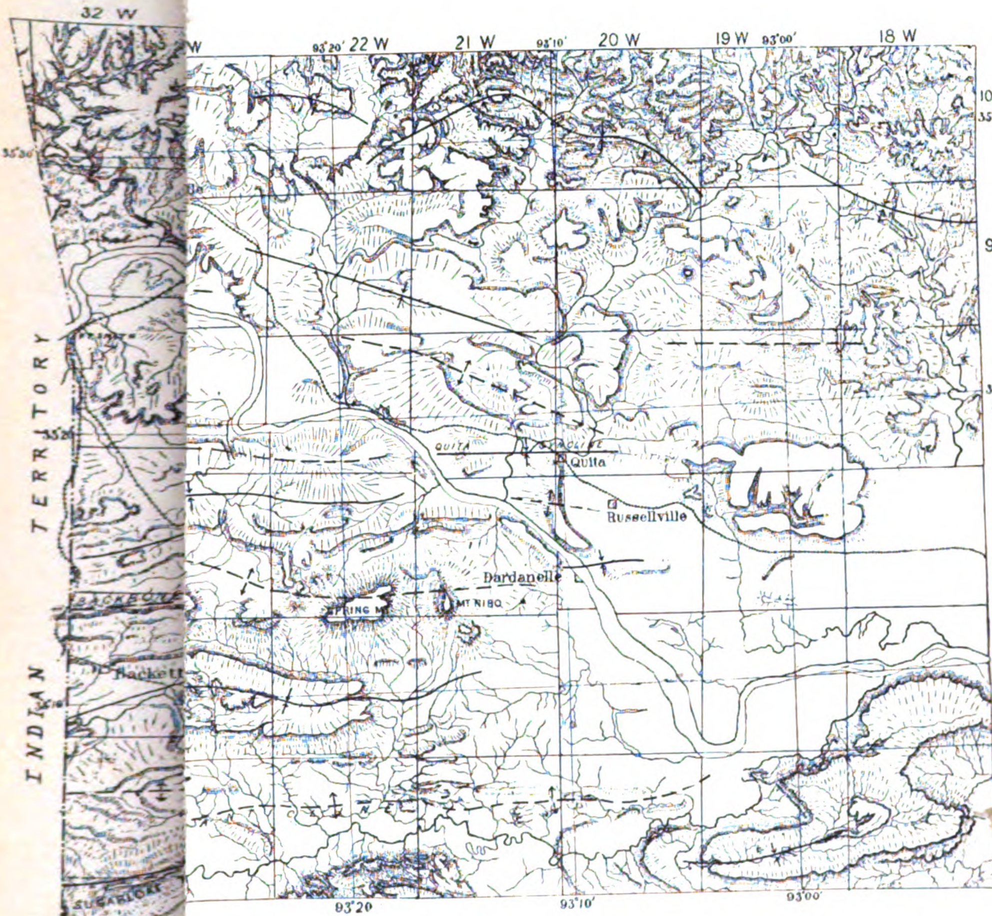
[illegible] between ridge and mesa implied by the above heading [illegible] cross-section which admits [illegible] into two classes. The first class, or that of ridges, [illegible] monoclinal backbones with [illegible] summit [illegible] immediately away from the crest [illegible] generally [illegible] cultivation. The second class, or that of [illegible] particularly the flat-topped or gently [illegible] horizontal structure, approaching the character of mesas [illegible] surrounding the broad summit. This [illegible] structural difference [illegible] insensible gradations.

[illegible] these ridges and hills [illegible] without order [illegible] will be seen, however, [illegible] system [illegible] valleys. These [illegible] considerably [illegible] prominence [illegible]

[illegible]

[illegible]

[illegible]



NIC AND TOPOGRAPHIC MAP

Of a portion of

Vestern Arkansas

Scale 1:568,149

15

indeed a very slight elevation in comparison with the cliffs of till of similar origin on some parts of the shores of Lake Michigan and others of the Laurentian lakes, where erosion has been in progress from the time of the glacial recession to the present day. Scarboro' heights on Lake Ontario, near Toronto, extending nine miles with a height of 170 to 290 feet, consisting of till and interglacial beds, are cliffs thus produced by postglacial lake erosion. The duration of the glacial lake appears to have been much shorter than the postglacial epoch.

It is important, however, to note here that cliffs of preglacial erosion, which remained as prominent escarpments through the vicissitudes of the ice age, became in some places the shores of glacial lakes. Of this class are the bold highlands of Pembina, Riding, and Duck mountains, which rise steeply 100 to 1,000 feet from the highest western shore line of Lake Agassiz, to form the margin of a plateau that stretches with a moderately undulating surface westward. Even where this lake washed the bases of the cliffs, it doubtless eroded them only to a slight extent. The horizontal Cretaceous beds of this great escarpment originally extended eastward a considerable distance, as believed by Hind and Dawson, probably so far as to cover the areas now occupied by Lake Winnipeg and the Lake of the Woods; and we must attribute the erosion of their eastern portion, leaving this steep line of highlands, to river action during the Tertiary era, not in any important degree to glaciation, and least of all to shore-cutting by the glacial lake.

Beaches.—The course of the shore of a large glacial lake is usually marked by a deposit of beach gravel and sand, forming a continuous, smoothly rounded ridge, such as is found along the shores of the ocean or of our great lakes wherever the land sinks in a gently descending slope beneath the water-level. The beach ridges of Lake Agassiz, and of the glacial representatives of the Laurentian lakes, commonly rise three to ten feet above the adjoining land on the side that was away from the glacial lake, and ten to twenty feet above the adjoining land on the side where the lake lay. In breadth, these ridges vary from ten to twenty-five or thirty rods. The beach deposit takes thus the form of a broad wave-like swell, with a smooth gracefully rounded surface. Like the shore accumulations of present lakes and of the sea coast, these glacial lake beaches vary considerably in size, having in any distance of five miles some portions five or ten feet higher than others, due to the unequal power of waves and currents at these parts of the shore. Moderate slopes bordering the greater glacial lakes were favorable for the formation of beach ridges, and such ground frequently displays many beaches at successive levels, which marked pauses in the gradual elevation of the land when it was relieved of its ice-burden, and in the subsidence of the lake as its outlet became eroded deeper or as the glacial retreat uncovered new and lower avenues of discharge.

[illegible]

[illegible]

[illegible] Rocky Mountains [illegible] determined by the [illegible] northwestern Montana, the [illegible] northeastern edge and the cen- [illegible] eastern parts of Washington [illegible] the altitude of [illegible]

[illegible] British Columbia and southern Alaska the ice-sheet [illegible] Coast Range and terminated in the sea from the

[illegible] Report, Plate [illegible].
[illegible] Society of Canada, [illegible], Plate II.

the last glacial epoch. The erosion of the valley therefore must have fallen far short of supplying the material of the Assiniboine delta, not to mention the fine silt and clay which were carried into the lake beyond the gravel and sand delta and may be of equal volume. Probably at least half of these lacustrine deposits were modified drift brought down by streams from the melting ice-sheet on the upper Assiniboine basin north of the mouth of the Qu'Appelle and swept forward by the strong current of the river until they could be deposited in Lake Agassiz.

Very recently a detailed section (plate 9) was made from Harvey, in the southeastern part of Marion county, along the line of the Des Moines river to the capital city and thence up the Raccoon river to De Soto, in Dallas county, a distance of sixty-five miles. The circumstances for its construction have been made very favorable by the numerous excellent exposures afforded by railway lines that have been built nearly the entire distance on each side of the two streams. These railway cuts, taken together with the natural outcrops on the rivers, permit the stratigraphy of the district to be very satisfactorily traced in all the minor particulars.

Along the line just specified, more than two hundred exposures were examined and measured, the different beds being carefully correlated in the field by direct passage from point to point. Out of this number, ten of the most instructive and typical sections have been selected, and descriptive notes are appended, indicating the salient characters of the various strata. Each is marked on the accompanying general section, the base of which is the low-water limit in the Des Moines river. It is thought that the two methods of illustration will adequately present, in the briefest possible manner, the leading geological features of the region. The stratigraphical relations of the several beds will find further explanation beyond.

The Quaternary deposits have not yet been differentiated with sufficient care to warrant the separation, in a general section, of the drift sheets and the löss.

Description of Sections.

I. Harvey Exposure.—Quarry in S. W. qr. N. W. qr. Sec. 4, *T.* 75 *N., R.* 18 *W.*

3. Drift and löss (exposed)	10 feet.
2. Gray and ash-colored marl, with abundant fossils: *Spirifera keokuk*, Hall; *Pentremites koninckiana*, Hall; *Zaphrentis spinulifera*, Hall; *Athyris subquadrata*, Hall; *Productus marginocinctus*, Prout; and others	5 "
1. Blue limestone, weathering brown in places, thinly bedded above (exposed)	12 "

II. Coalport Section.—S. E. qr. S. W. qr. Sec. 4, *T.* 76 *N., R.* 19 *W.*

6. Heavily bedded sandstone, with lepidodendrids, sigillarids, filices and calamites below (exposed) . . .	15 feet.
5. Dark-colored clays and shales, sandy in places . .	30 "
4. Coal (mined at this place)	5 "
3. Dark clays and bituminous shales	14 "
2. Coal, rather impure	2 to 3 "
1. Sandstone, very thinly bedded, and sandy shales (exposed to water's edge)	8 "

No. 6 of this section is not exposed on the river bluff at this place, but crops out in a ravine some distance inland.

Lithological Features of the Strata.

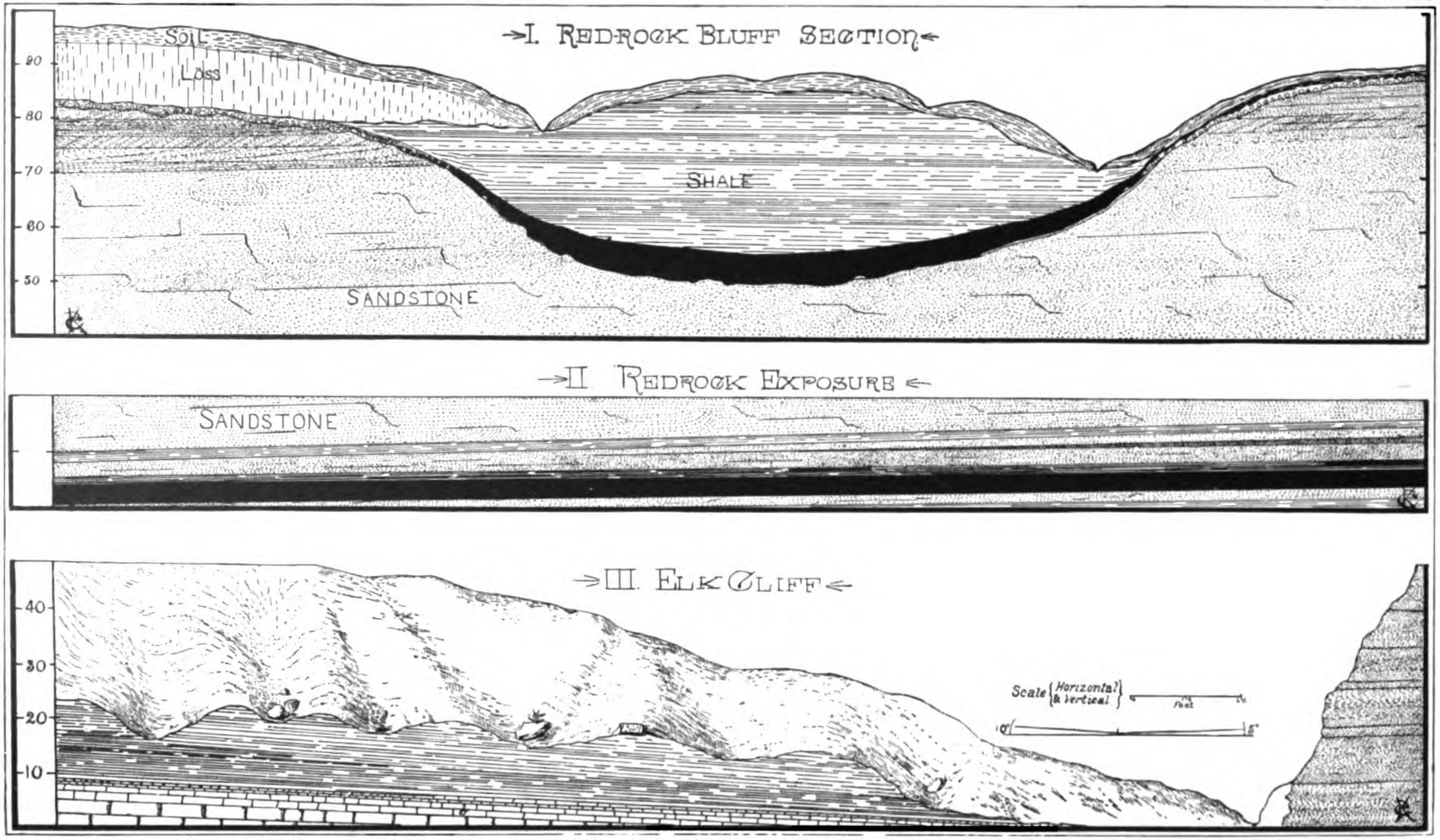
General Characters.—In lithological characters the Coal Measures of central Iowa contrast sharply with the other Paleozoic formations of the state. Not less striking is the relative thinness, as a rule, of the individual layers, or beds, which follow and replace one another, upwards and laterally, in rapid succession. Often within a vertical distance of a few inches or a few feet, layers of sand, clay or shale are succeeded by different strata; or else are changed both in color and chemical composition. Of the three general types of rocks recognized, the argillaceous are the most prominent and most widely distributed; arenaceous deposits are developed only in much less volume; while the calcareous rocks are exceedingly unimportant and are restricted to a few thin bands, seldom more than eight or ten inches in maximum thickness.

Argillaceous Materials.—The clay-shales make up by far the greater portion of the Lower Coal Measures in Iowa. On exposure to atmospheric agencies they quickly disintegrate into soft clays and are easily carried away by running water. For the most part they are ashen, drab, or black in color, though red, yellow, buff and blue shades are of not uncommon occurrence. In some localities the variegated shales—blue, drab, red, yellow and ashen indiscriminately mingled—predominate. It is in the latter shales that crystallized gypsum frequently occurs abundantly. At Des Moines and elsewhere, diamond-shaped crystals of selenite are the more plentiful, though not infrequently some of them are greatly elongated in the direction of the vertical axis, sometimes attaining a length of eight or ten inches. In the latter habit, twinning is quite common. Often the crystals are acicular and, radiating from a center, form little rosettes, which lie in great numbers on the exposed surfaces of clays.

The light-colored shales occasionally afford impressions of ferns and lepidodendron roots, but for the most part they are unfossiliferous. The dark-colored, bituminous varieties, on the other hand, are often highly charged with organic remains. From a single locality (Des Moines) nearly one hundred species of invertebrates have been recognized, besides a number of fossil fishes and plant remains. A partial list of these organisms, with full notes, has been given in another place,* and considerable additional information of the same sort will soon appear in a form for reference.

The light-colored shales, by the gradual addition of fine, sandy material, pass imperceptibly into sandy shales, and these again into shaly sandstones and finally into hard, compact sandrock. This gradual transition may take

* Proc. Acad. Nat. Sci., Phila., 1888, pp. 222-246.



UPPER AND LOWER LIMITS OF THE REDROCK SANDSTONE.

and variety of the strata of the Calciferous and Chazy zones were greatly underestimated, and their wealth of fossils was unsuspected. Had it been otherwise, Billings would have had to describe fewer new species from the Lower Silurian of Canada, and some of the difficult problems of the "Quebec group" would have been more easily solved.

We purpose, in the present paper, to present a comparative view of several representative sections of the Chazy formation in the Champlain basin. We shall omit all details of stratigraphy, and present only the results of our study as regards the thickness and sequence of the strata and their characteristic fossils. These local details have been thoroughly worked out, and will be presented elsewhere with maps and sections giving actual profiles and dips. In the diagram herewith presented (plate 11) the strata are restored to the horizontal attitude so as to indicate more clearly the correlation of the beds in the several sections.

A further preliminary statement should be made concerning the boundaries of the Chazy. The upper boundary is the Black River, a black, massive pure limestone, 30 to 50 feet in thickness, easily recognized and remarkably uniform throughout the Champlain valley. The lower boundary, or the top of the Calciferous, is less distinctly recognized by geologists. We have considered it to be a tough iron-gray, fine-grained, magnesian rock, usually weathering yellowish or drab, 300 to 400 feet in thickness. Wherever this horizon is exposed in the lake region, these magnesian rocks appear, though they are wanting in the region east of the lake. The few fossils that occur in occasional beds of limestone, and the general lithological character of the mass, would seem to ally it to the strata below. Furthermore, whenever any of these outcrops are mentioned by the older geologists, the rock is always referred to the Calciferous.

The Detailed Sections.

Section at Valcour Island.—The first section of the Chazy to be described is that of Valcour island, about six miles south of Plattsburgh, New York. This island, two miles in length and one mile in breadth, with deep bays and high promontories, consists almost wholly of the Chazy rock, which here attains a maximum thickness of nearly 900 feet. The island seems to have been hitherto unexplored by the geologist. On Professor Emmons's map of Clinton county it is colored as Calciferous; but no Calciferous rock occurs except at the southern extremity just beneath the usual level of the lake. Above it appear the strata of the Chazy, dipping 20° or 30° eastward, and rising in cliffs 30 to 50 feet in height along the southeastern shore. It is the most impressive display of limestone to be seen along the lake. From a boat we can here behold, in one view, measures of the Chazy over 600 feet

Crown Point Section.—Westward from Cornwall, toward Lake Champlain, the beds of the Chazy rapidly decrease in thickness. The same fact is noticeable southward from Valcour along the lake shore. The top and the bottom of the formation are the first to disappear. Neither the "*Rhynchonella* beds" nor the "slaty limestone" are to be seen south of Valcour. The Lower Chazy and Upper Chazy contract to small proportions, and finally disappear. Then the Middle Chazy begins to contract, and also disappears.

We present a carefully measured section at Crown Point fort to illustrate this fact. We find there in ascending order:

A	1. Sandstone and slate interstratified	23 feet.
	2. Impure limestone containing *Orthis platys*, Bill. . .	25 feet.
B.	Beds containing *Maclurea magna*, Leseuer . . .	200 feet.
C	1. Dark-gray, massive limestone, weathering in darker stripes, an inch wide, containing the large *Bucania* seen elsewhere at this horizon	40 feet.
	2. Tough silicious and magnesian rock passing into a two-foot bed of pure sandstone	17 feet.
	Aggregate thickness	305 feet.

Orwell Section.—An exposure in Orwell, Vermont, one mile northeast of the village, presents only 50 feet of *Maclurea* strata lying between the Calciferous and the Black River.

Distribution of the Chazy.

West and south of this point, through central New York and the tract west of the Adirondack region as far north as the Thousand Islands, the Chazy is altogether lacking. When it reäppears to the northward, along the Ottawa river and in the vicinity of Montreal, it apparently consists of the measures that first disappear to the south in the Champlain valley. They are described by Logan as whitish sandstones interstratified with bands of green shale, followed by beds "composed almost entirely of *Rhynchonella plena*," and are supposed not to exceed 150 feet in thickness. This answers well to the top and bottom of the Valcour section. No beds containing *Maclurea magna* are reported from Canada to the west of the outlet of Lake Champlain. These facts could be easily accounted for by supposing at the north an elevation of the sea-bed during the middle of the Chazy period, and at the south a simultaneous depression and submergence. If in the intervening region the submergence was continuous, we should have the whole formation and the maximum thickness at the northern end of Lake Champlain.

Eruptive Rocks.—The rocks of undoubted eruptive origin within the eastern or more highly crystalline area of Maryland are very abundant and varied. The extensive dynamic metamorphism to which they have been subjected has developed in them many features tending to disguise their original character and to confuse them with highly altered sediments. These rocks have been the most carefully studied and described of any occurring in Maryland, so that for the present purpose it will be sufficient to merely enumerate the more distinct varieties, together with references to the various articles which contain details of their character and alterations. These eruptive rocks may be arranged under three distinct types: *

Intermediate Type (the most ancient), comprising:

a. Hypersthene gabbro; †
b. Gabbro-diorite and its metamorphic product, hornblende schist; ‡
c. Quartz gabbro, Harford county;
d. Norite, Harford county;
e. Diorite, Ilchester; §
f. Hornblendite;
g. Hornblende-biotite-quartz-diorite, Washington.

Basic Type, comprising: ||

a. Pyroxenite (Websterite); ¶
b. Lherzolite; **
c. Cortlandtite, Ilchester; ††
d. Serpentine, resulting from the alteration of all the preceding basic rocks.

Acid Type, comprising:

a. True or binary granite, Guilford;
b. Granitite, with allanite-epidote growths; ‡‡
c. Hornblende granite, Garrett Park; §§
d. Granite porphyry, Ellicott City;
e. Augen-granite gneiss, Texas, Baltimore county;
f. Felsite (quartz-porphyry), in dikes at Relay;
g. Pegmatite (muscovite-biotite). ||||

Rocks whose eruptive origin is either undoubted or most probable cover at least half of the now exposed surface within the eastern or more crystal-

* See Am. Geologist, vol. 6, July, 1890, p. 36.
† Bull. U. S. Geol. Survey, no. 28, 1886, p. 18.
‡ Ibid., p. 27.
§ Hobbs: Johns Hopkins University Circulars, no. 65, 1888; and Trans. Wis. Acad. Sci., vol. 8, November 10, 1890, p. 157.
|| Bull. U. S. Geol. Survey, no. 28, 1886, p. 50.
¶ Am. Geologist, vol. 6, 1890, p. 40.
** Ibid., p. 38.
†† Hobbs: Loc. cit.
‡‡ Hobbs: Johns Hopkins University Circulars, no. 65; Tschermak's min. petr. Mitth., vol. 11, 1889, p. 1.
§§ Keyes: This volume, p. 321.
|||| Johns Hopkins University Circulars, no. 38, vol. 4, 1885.

the same easterly dip the thick beds of sandstone which compose Sugarloaf mountain. These thin out toward the north to a few insignificant sandstone patches, while toward the south they soon disappear beneath the Newark transgression. The Sugarloaf sandstone passes on its eastern side upward by a gradual transition through shaly layers into sandy slates, and these again into the succession of sericite and chlorite schists, which compose the mass of the semi-crystalline area. Beneath the sandstone the shales are more disturbed, and, as there is here no such transition, this surface may represent a fault or thrust, as suggested by Mr. Keyes.*

The main body of semi-crystalline rocks in the Piedmont region are slatesand soft schists and, north of the Baltimore and Ohio main stem, narrow limestone bands, which preserve a constant north to north-northeast strike. The dip of these rocks is always toward the east as far as a line (the axis of the fan) which runs nearly north from Great Falls, where they become vertical. Toward this axis the dip becomes constantly steeper and steeper, yet the character of the rocks is but little changed save that they become gradually more shattered and crinkled.

After passing the vertical axis, the same structure is observed on the east as on the west, but in an inverse order. The dip of the strata turns gradually toward the west, becoming less and less steep as we proceed from the axis toward the coastal plain. As may be seen from the map, all the westerly dipping strata in the southern part of the Piedmont region, where the axis is nearly coincident with the boundary between the eastern and western

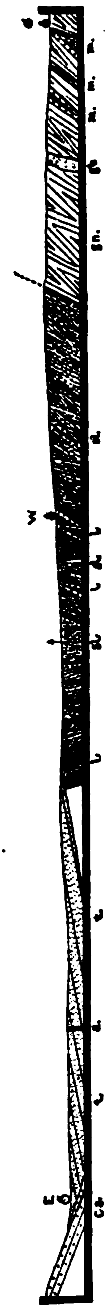


FIGURE 1—*Northern Section through the Piedmont Region in Maryland.*

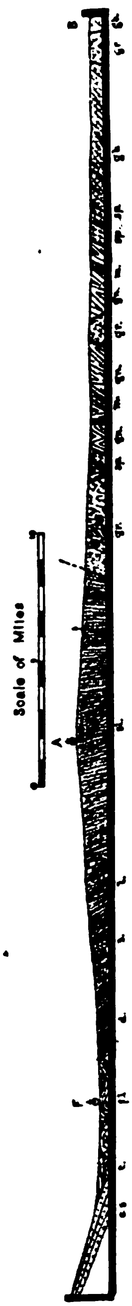


FIGURE 2—*Central Section through the Piedmont Region in Maryland.*

* The course of the great Triassic trap dike, which extends from Emmitsburg entirely across the state (see map), is worth noticing in this connection. It is nearly parallel to the synclinal axis of the Piedmont plateau, and may represent a preëxisting line of weakness in the crust.

(3) the extensive superficial decay to which they have been subjected. As we approach their eastern boundary the semi-crystalline rocks exhibit the effects of more intense dynamic action. Along the axis, where they stand vertical, and also east of it, they are much broken, crinkled, and corrugated. Still, all the disturbance and alteration observed in the semi-crystalline schists may be readily accounted for by a single earth-movement; *i. e.*, by a force acting for a long time in a single direction.

The rocks of the eastern area, as the preceding petrographical descriptions have shown, are, in spite of a certain correspondence of sedimentary types, broadly distinguished from the schists and slates of the western area. They have, indeed, by the most complete metamorphism and recrystallization, lost nearly all traces of any clastic structure which they may once have possessed. This general distinction is admirably illustrated by Mr. Keyes in his two figures of the microscopic appearance of the quartz-schist of the eastern area, and a sandstone of the western area (this volume, page 321). These rocks may once have been nearly identical, but, if so, the former has lost its original structure quite completely.

The much greater variety of rocks within the eastern area is largely due to the ancient eruptives, which are there so abundant. But these hard and resistant masses have suffered hardly less complete foliation and metamorphism than the sediments which surround them, while in both this action is far in excess of what has taken place in any portion of the western area.

Another point of great importance is the abruptness of the passage from the semi-crystalline to the holocrystalline rocks. The schists at Westminster are hardly more crystalline than those bordering the Frederick valley, while so soon as we pass the boundary line between the two areas we meet gneisses as granitoid and perfectly crystalline as any to be found within the whole eastern district.

The holocrystalline rocks occupy all the Piedmont area in Maryland east of the eastern base of Parr's ridge, except the infolded and overturned mass of soft schists surrounding the Peach Bottom and Delta roofing-slates, which descend in a south-southwesterly direction from York and Lancaster counties, Pennsylvania* (see map, plate 12). Throughout all of the Piedmont area in Maryland east of the axis there is the general tendency to westerly dip above alluded to, and yet this feature is so much less constant in the holocrystalline than in the semi-crystalline rocks that it indicates a structure added to others which it has only partially obliterated. The very irregular areas occupied by the different rocks, the abrupt changes in trend and structure, and the much more intense alteration of the sedimentary beds, all bear

* There is a similar occurrence of slates between Occoquan and Quantico, in Virginia, apparently wholly on the eastern side of the crystallines; but here the rocks lying still farther eastward are buried beneath the formations of the coastal plain. At Occoquan the granite west of the slates is intrusive into them.

of age for the semi-crystalline and holocrystalline rocks we may summarize the following points:

a. The structure is not really a synclinal, but a fan-like divergence of dip from a central vertical axis, such as could not be produced by any synclinal bending in a continuous series of similar beds.

b. Any cause altering any part of an original series more than another would not make an *abrupt* contact, such as we find between the semi-crystalline and highly crystalline rocks of Maryland, but a gradual transition.

c. Any cause altering one flank of a synclinal more than the other would make the contact between the two kinds of rock and the axis of the synclinal coincide, as is not the case in Maryland (see map, plate 12).

d. The eruptive rocks of the eastern area are found in many places in close proximity to the slates or schists, without having effected their alteration; hence they are either not the cause of metamorphism, or they are themselves older than the semi-crystalline rocks; and, moreover, the sudden disappearance of the abundant eruptive rocks at the edge of the western area is itself a strong reason for supposing that it is of later age.

e. We cannot suppose that excessive dynamic action was the cause of the metamorphism, because where we should expect the folding force to have acted equally we find the hardest rocks (eruptives) much more altered, foliated, and disturbed than the soft argillites.

In face of the facts, we seem, therefore, obliged to admit that the boundary line between the semi-crystalline and holocrystalline portions of the Maryland Piedmont area represents a great time-break. Their contact is not an absolutely sharp line, nor indeed is this to be expected, since, as Professor Pumpelly has recently pointed out, one formation may pass gradually into one lying unconformably above it in consequence of superficial rock decay;* and also since any metamorphism such as both these areas has undergone tends strongly to obliterate sharp lines of contact. Still, while not absolutely sharp, this contact is far too abrupt to accord with any supposition of a gradual or progressive metamorphism through the entire series from west to east.†

The second and third of the above-mentioned hypotheses assume the difference in age of the western schists and eastern gneisses and eruptives, which it is the main object of this paper to establish. The second hypothesis (*i. e.*, that there was a passively resistant buttress of crystalline rock) is,

* This volume, pp. 209-224.

† If the boundary of the semi-crystalline rocks of Maryland against the holocrystalline rocks really represents a great time-break, it may seem remarkable that basal conglomerates have not been encountered near this line. These may exist, but as yet they have not been clearly identified. Their presence is, of course, not necessary to prove the unconformity, although they are to be looked for. It is not impossible, as stated on page 309, that the conglomeratic sandstone which occurs on Deer creek, Harford county, between the gneiss and Peach Bottom slate area, may be of this nature.

the widely spread *Leptæna sericea*, Sowerby. Meek's *Orthis desmopleura* from the Chazy of Colorado seems to be very closely related. The species here noticed are characteristic of the Trenton period. This fact, taken in connection with the stratigraphic position of the fossiliferous horizon, leaves little room to doubt that the strata here referred to are of Trenton age. But, as already intimated elsewhere, the entire series of limestones and shales between the two great sandstones of the Catoctin and Sugarloaf mountains probably represents the Chazy, Trenton and Hudson River formations of the more northern localities.

In passing westward along the line of the section, the Piedmont plateau gradually increases in elevation above sea-level from about 200 feet on the eastern border to nearly 600 feet at the base of Sugarloaf mountain. This prominence rises abruptly to a height of almost 1,300 feet above mean tide. The broad Frederick valley beyond has an elevation scarcely higher than the eastern part of the plateau. Lastly comes the Catoctin range, which rises nearly to an equal height with Sugarloaf. Both mountain crests are formed of hard sandstone, shown in thin sections to be of unmistakable clastic origin (figure 4). The rocks between are contorted limestones and slates, the former being overlain by Newark (Triassic) sandstone for more than half its supposed extent. The Sugarloaf sandstone is seemingly identical with that of the Catoctin. By a double thrust it apparently presents twice its actual thickness, the upper member forming Sugarloaf itself, and the other member forming a somewhat lower elevation immediately west of the mountain. By the intercalation of numerous thin argillaceous bands the great sandstone rapidly loses its sandy character and passes gradually into typical phyllites. These schistose rocks, in broad alternating hydromicaceous and chloritic belts, have a superficial extension half way across the plateau. At first the cleavage planes have a low angle and are parallel with the inclination of the great sandstone; but gradually the inclination becomes greater and greater until near the axis, at Derwood station, it is perpendicular. Near Sugarloaf these planes have the appearance of being coincident with the lines of strati-

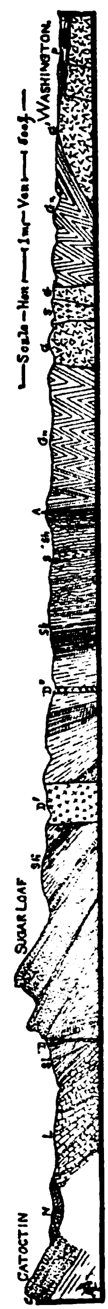


FIGURE 3.—*Southern Section through the Piedmont Plateau in Maryland.*

C = Catoctin sandstone; N = Newark (Triassic) red sandstone, with northwesterly dips; L = Frederick valley limestone; Sh = Hydromicaceous and chloritic schists; Sl = Slates; D = Mesozoic diabase dike; D' = Buck Lodge diabase; D'' = diabase dike; S = Serpentine (two belts); A = Axis, near Derwood station; Gn = Gneiss; G, G = Granitoid gneiss, with abundant inclusions; G' = Granite, in part hornblendic; P = Potomac clays and coastal plain deposits.

mechanical deformation, the edges and angles being ground away and the fragments still filling the interstices. The larger quartz grains exhibit, between crossed Nicols, marked undulatory extinction—a phenomenon quite characteristic of granitic masses that have been subjected to great dynamic action.

Considerable interest attaches to the structure of Sugarloaf mountain, which was incidentally a subject of consideration in the construction of the section across the plateau proper. The thick massive sandstone forms a monoclinal with easterly dip. As regards the somewhat lower elevation to the west of the mountain, two hypotheses are presented, either of which would offer a satisfactory explanation; but the substantiation of one or the other is immaterial in the present connection. There may have been a double thrust, thus giving the sandstone a measurement twice as great as the actual thickness; or the crests of the two elevations may represent parts of the same formation in which only a small amount of sliding movement has taken place. The former of these suggestions, however, appears the more probable.

As already stated, the upper portion of the sandstone passes gradually, by intercalation of thin argillaceous bands, into the schists lying to the eastward. These schists, for a considerable distance from the mountain, show no apparent contortion. Thin cleavage planes are coincident with the dip of the Sugarloaf sandstone. The regular succession of numerous thin argillaceous and sandy layers above the massive portion of the great sandstone would, therefore, seem to indicate that the cleavage directions of these rocks are true planes of stratification. In some of these undisturbed transition beds toward the superior limit of the great sandstone the alternation of different lithological materials is so marked that layers of sandrock, in every respect identical with the Sugarloaf stratum, and only from four to twelve inches in thickness, regularly succeed equally thin seams of fine clayey sediments. In places the effect of the light buff color of the narrow sandstone bands and the dark blue-black layers of the argillites is very striking.

The slates on the western side of the Sugarloaf prominence are variously inclined, from nearly perpendicular to a comparatively low angle. They appear in places considerably puckered.

When the region was subjected to intense orographic pressure, the softer rocks were finely crinkled and puckered. On the other hand, the great thickness of sandstone was but little affected internally. It was faulted and, acting in large units, apparently slid over the softer layers. The facts as here presented show that below the sandstone the shales are more or less disturbed; while above, the argillites are not at all affected, and appear interstratified with the upper portions of the arenaceous formation. This would point strongly to the conclusion that the plane of movement or thrust was at the bottom rather than the top of the great Sugarloaf sandstone.

great lava-flows; similar flows are found also in abundance in the region south of the Bay of San Francisco. None of these flows are older than the Pliocene, and many of them undoubtedly belong to the Quaternary. There is, therefore, abundant evidence of orogenic changes in late Pliocene and early Quaternary times sufficient to divert the lower courses of the rivers.

In brief, then, the general character of the changes in the Coast range region was as follows: During the Miocene the coast line was somewhere to the east of the Coast range, and the place of that range was marginal sea-bottom. At the beginning of the Pliocene the Coast range was formed, and the coast line was transferred westward beyond its present position to the border of the submarine plateau. During the Pliocene, continental elevation commenced, and culminated at its end or perhaps in the early Quaternary. All the islands bordering the coast, especially the high islands off the coast of southern California, were added to the continent. Meanwhile the rivers, whether rising in the Coast range or breaking through gaps in that range, cut their channels deeper and deeper. At the beginning of the Quaternary, coincident with the great orogenic changes and lava-flows of the Sierra, there occurred also great lava-flows in the coast region which modified the orographic forms of the Coast range and changed the lower courses of the rivers. Soon after these orogenic changes the coast region went down to, or indeed considerably below, its present level and the deserted lower channels were submerged. The fact that they were deserted, and that therefore they were unmodified by subsequent sedimentation, is the reason they run in so near shore and are so distinct. From this subsided condition, abundantly shown by elevated sea margins both on the mainland and on the high islands off the southern coast, the land was again raised to its present level. This, however, is far below its former position, and therefore the channels remain submerged.

Changes in Rivers.—Concerning the courses of the Pliocene rivers which cut these channels we know nothing and it is vain to speculate; this must be left to future investigation. But there is one river, and that the greatest in California, concerning which some words may be not wholly profitless.

At the present time the tributaries of the Sacramento and San Joaquin pour their united waters into the Bay of San Francisco and through the Golden Gate into the Pacific. But this outlet certainly did not exist in Pliocene times, for there is no submarine channel off the Golden Gate. Where then did the river empty at that time? Probably far southward into the Pacific, off the Bay of Monterey. Professor Davidson tells me that a depression of 100 feet at the divide between the bays of San Francisco and Monterey would now empty the waters of the former into the latter. Is it not probable, then, that the deep channel running in close to shore in Monterey bay may be the submerged Pliocene outlet of this great river? If so, then the history of this river may be as follows:

mous, in consequence of the reluctant yielding of the crust and the capacity of ice to reproduce the conditions of its own accumulation. Although the elevation produced the cold and therefore the ice-accumulation, yet the latter culminated long after the former had ceased and even after a contrary movement had commenced.

I have been accustomed to illustrate this view by the accompanying diagram, figure 1. In this diagram, which, for simplicity's sake, treats the glacial epoch as one, the horizontal line, *A B*, represents time from the later Pliocene until now; but it also represents the present condition of things both as to land-level and as to ice-accumulation. The full line, *c d e*, represents the oscillations of land (and presumably of temperature) above and

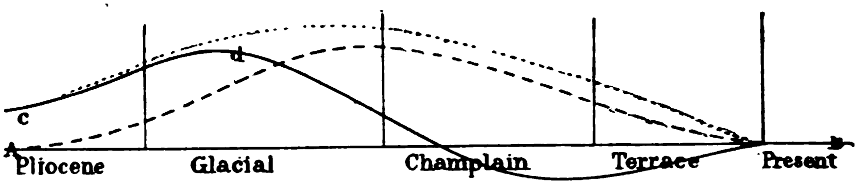


FIGURE 1.—*Graphic Representation of Quaternary Climate and Land-Altitude.*

below the present condition. The broken line represents the rise, culmination and decline of ice-accumulation. The dotted line represents the crust-movement as it would have been if there had been no ice-accumulation.

It is seen from the diagram that the ice-accumulation culminated at a time when the land, under the pressure of the ice-load, had already commenced to subside; and that the subsidence was greatest at a time when the pressure had already commenced to diminish. But the fact that the land, after the removal of the ice-load, did not return again to its former height in the Pliocene, is proof positive that there were other and more fundamental causes of crust movement at work besides weighting and lightening. The land did not again return to its former level because the cycle of elevation, whatever its cause, which commenced in the Pliocene and culminated in the early Quaternary, had exhausted itself. If it had not been for the ice-load interfering with and modifying the natural course of the crust movement determined previously and primarily by other and probably internal causes, the latter would probably have taken the course represented by the dotted line. It would have risen higher and culminated later, and its curve would have been of simpler form.

ley from a third, or "West Rutland valley," which in turn is bounded by the higher ridges of the Taconic range.

In the high, abrupt frontal range of the Green mountains there occur crystalline schists, often gneissic, which pass eastward into the gneissic rocks

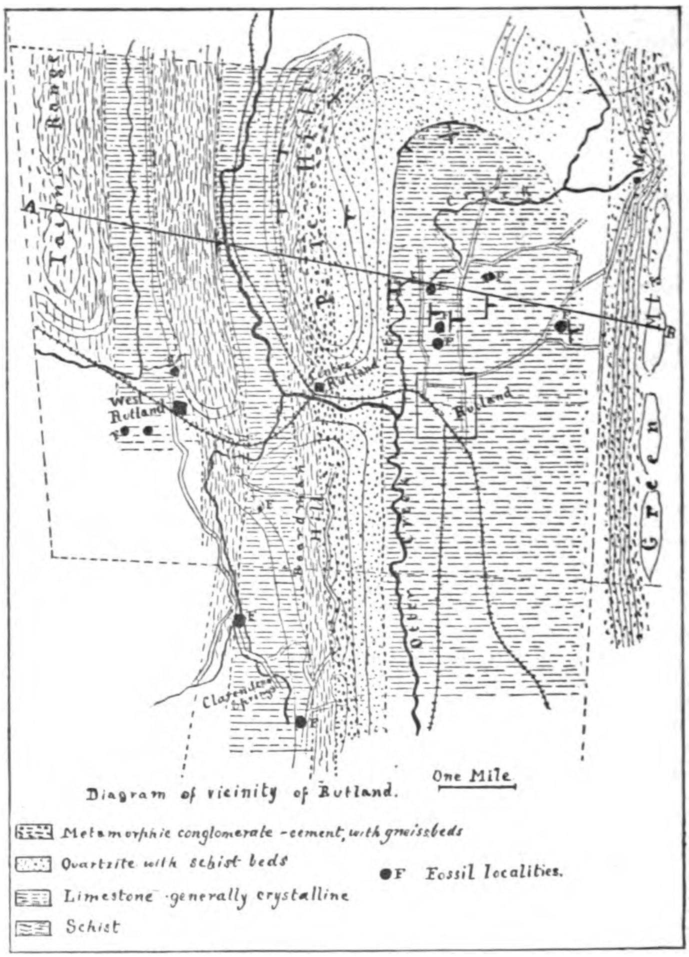


Figure 1.

proper of the Green mountains. These schists contain beds of true conglomerate, with a metamorphosed crystalline cement, and pass westward, on the slope, into the quartzite of Vermont, which the discoveries of C. D. Walcott prove to be of lower Cambrian age (*Olenellus* zone). This is succeeded

The first, about three miles south of the railroad, half a mile southeast of Clarendon Springs, is on the north side of a barn standing on the west side of the hill road to Centre Rutland. The bluish sandy limestone contains numerous crinoid stems and occasional plates, and rarely a small branching bryozoan with large cells. The forms are identical with those in the West Rutland valley. The locality is near the eastern border of this (Centre Rutland) belt.

The second locality is a few feet from the contact of this limestone with the schists on the west. It is in the northwestern corner of Clarendon township, in the bed of a stream crossed by the road from West Rutland to Clarendon Springs, about two hundred feet east of the covered bridge. A few crinoid stem rings were found here. This locality is about two and a half miles south of the railroad.

The third locality is barely a mile south of the bend made by the railroad in passing from Centre Rutland to West Rutland. It is on Boardman hill (the southern continuation of Pine hill), a few hundred yards south of the road ascending the hill from West Rutland, three hundred feet northwest from a new marble quarry, and about two hundred feet across the strike from the western edge of the limestone. The fossils found consist of a few crinoid stems.

The belt of limestone in which the fossils occur at these three localities was traced almost without break to Centre Rutland and into the Centre Rutland belt. In the same way the schists bounding it on the west were followed into the schist ridge separating the Centre Rutland and West Rutland limestone belts.

It seems therefore established that the Centre Rutland belt is of the same general age as that of West Rutland ("Trenton-Chazy-Calciferous"), and that the Cambrian Rutland limestone is either not represented in it at all, or at best by a very small strip.

Conclusions as to Structure.—The writer has given little attention to the structure of the schists between the Centre Rutland and West Rutland valleys. The cleavage dips steadily eastward, but the positions of the stratification planes can be seen to vary greatly both in direction and amount of dip, so that only careful study can determine the true structure. The same statement must be made regarding the West Rutland limestone and the schists of the Taconic range beyond.

The facts here stated prove that the limestone of the Rutland valley is of lower Cambrian age; that in Pine hill it overlies conformably a massive quartzite, with associated beds of metamorphic conglomerate, cement rock, crystalline limestone, and gneiss, which bend around to join the similar series lying east of the limestone; and that the Pine hill quartzite must therefore be of *Olenellus* age, while the limestone, bounded on the east and west

to be nearly the same. The large amount of magnesia (10.3 per cent.) in G. H. Cook's analysis of the trap from the palisades of the Hudson is worthy of notice.

E. S. Dana * made a microscopic examination of numerous specimens of trap from Connecticut, and of a few individual specimens from Nova Scotia, New Jersey, Pennsylvania and North Carolina, and found that, so far as microscopic structure goes, the rock from these distant localities is hardly to be distinguished from the trap of the Connecticut valley. He gave the composition of the rock to be "pyroxene, labradorite and magnetite, with also occasionally some chrysolite and apatite." He, too, called it dolerite.

G. W. Hawes † discovered a glassy ground-mass in certain modifications of these rocks, and mentioned the occasional presence of biotite and hornblende. Excepting local modifications, he considered the rocks to be like the ordinary old diabases, and in microscopic features to be monotonously alike wherever fresh stones occur.

J. P. Iddings ‡ examined microscopically the igneous rocks occurring in the earlier Mesozoic area at Orange, New Jersey, and found some of them to be holocrystalline and others to contain glass. He says the former should be called dolerites and the latter basalts.

N. H. Darton, § in speaking of the igneous rocks of the New Jersey Mesozoic region, says that they are remarkably uniform petrographically, as they are all basalts, varying mainly in structure and development.

These references are sufficient to show that the trap rocks of the earlier Mesozoic areas upon the Atlantic border have been considered essentially alike in mineral and chemical composition, whether called dolerites, diabases, or basalts.

TRAPS OF EXCEPTIONAL COMPOSITION.

Varieties.—We are glad to be able to bring to notice two interesting varieties to break the monotony of these igneous rocks. On account of the conspicuous occurrence of hypersthene in one variety, and of olivine together with hypersthene in the other, we have called the former *hypersthene-diabase* and the latter *olivine-hypersthene-diabase.*

The palisade area of Triassic rocks extends from the Hudson river, through New Jersey, Pennsylvania and Maryland, into Orange county, Virginia. As early as 1839, W. B. Rogers ‖ called attention to the trap of the part of this area lying in Virginia as being a very conspicuous feature from a geological point of view. He mentioned the occurrence of ridges, knobs and

* Am. Jour. Sci., 3d ser., vol. VIII, 1874, p. 390.
† Proc. U. S. Nat. Mus., 1881, p. 129.
‡ Am. Jour. Sci., 3d ser., vol. XXXI, 1886, p. 331.
§ Bulletin U. S. Geol. Survey, no. 67, 1890, p. 15.
‖ Geology of the Virginias, 1884, p. 475.

railroad in Culpeper county, Virginia, about two miles north of Rapidan station. This rock weathers into globular masses and contains olivine throughout, so far as we could judge from making numerous thin sections.

Description of the Hypersthene-Diabase.—The hypersthene-diabase has a medium grain and is of a dark-gray color. The darker varieties have a somewhat greasy luster. The unaided eye can detect two dark minerals, the one nearly black, and the other deep honey-yellow or brown in a very light-colored background. Sometimes the light material occurs as small irregular veins running through the darker rock.

In thin sections we were able to distinguish triclinic feldspar, diallagic augite, hypersthene, biotite, apatite and occasional quartz, hornblende and probably zircon. Black opaque grains were also present, and as these were magnetic and some of them showed a trace of titanium, they were considered to be magnetite and ilmenite.

The structure is generally ophitic. It seems to be intermediate between the granular structure of gabbros or norites and the porphyritic structure of the holocrystalline varieties of the augite-porphyrites, shading sometimes into the former, sometimes into the latter. It is owing to the predominant ophitic structure alone that we place these rocks among the diabases. The mineral composition would give them a place among the gabbros, for the monoclinic pyroxene is diallagic. The hypersthene, however, more closely resembles that found in the hypersthene-andesites. These rocks afford another illustration of the view that the difference between gabbros and diabases is structural rather than mineralogical.

Constituents of the Hypersthene-Diabase.—The feldspar makes up all of the light material which is visible to the naked eye. In thin sections under the microscope it appears principally as lath-shaped crystals, polysynthetically twinned. In typical specimens these crystals are rarely larger than 1.5 mm. in length by 0.3 mm. in width, the majority being much smaller than these. Tabular crystals also occur, but they are not very common. Truly idiomorphic crystals are rare. Zonal structure is frequently visible with crossed Nicols, and the angle of extinction of the central part is greater than that of the margins. Minute crystals of apatite and other inclosures occur here and there. The angle of extinction, measured between twins which extinguish equally on two sides of the twinning plane, was as large as 36° in a number of instances, which points to the presence of anorthite.

Two analyses of pure white material, separated by means of the Klein solution, between the densities 2.672 and 2.704 gave the following results:

Analyses of Feldspar.

	I.	II.	Ratio of I.	
SiO_2	51.40	51.03	.856	.856
Al_2O_3	30.98	31.15	.304	.305
Fe_2O_3	.22		.001	
MnO	trace	trace		
CaO	13.40	13.92	.240	.250
MgO	.45	.59	.010	
K_2O	.39	.39	.004	.050
Na_2O	2.85	2.85	.046	
	99.69	99.93		

$\overbrace{R_2O : RO} : R_2O_3 : SiO_2 = \overbrace{1 : 5} : 6 : 17$, which gives $5\,(Ca_2Al_4Si_4O_{16}) : 2\,(Na_2Al_2Si_6O_{16})$ or 5 An : 2 Ab.

The analyses show this part of the feldspar to be labradorite. The optical properties mentioned above point to the presence of anorthite. We judge, therefore, that there are at least two varieties of feldspar present.

The monoclinic pyroxene is nearly black when the grains of it are seen in reflected light. In thin sections the grains always have an irregular outline. Very feeble diochroism from greenish gray to greenish yellow can be detected. In most sections the interference colors are brilliant. Crystals cut parallel to the clinopinacoid show an angle of extinction slightly greater than 40°. Sections in which the perfect prismatic cleavage is at right angles give an axis in converging light. Such sections also show cleavage parallel to the clinopinacoid and interpositions and cleavage parallel to the orthopinacoid. This latter cleavage is the principal, if not the only, way of distinguishing between diallage and augite in thin sections. The resemblance to the diallagic augite, described by E. Boricky as occurring in the melaphyres from Bohemia,* is in some particulars quite striking. The interpositions are so numerous as to give the augite a fibrous appearance in ordinary transmitted light. They can be resolved with a high power into fine needles lying in planes parallel to the base, with their long direction parallel to the orthodiagonal. Hence, in sections from the orthodiagonal zone, they appear as parallel lines of acicular microliths, while in clinopinacoidal sections they appear as points, arranged in lines making an angle of about 74° with the prismatic and pinacoidal cleavages.

Simple and polysynthetic twinning parallel to the orthopinacoid is quite common. Clinopinacoidal sections of such twins show the lines of interpositions meeting each other at an angle of about 150°. In polarized light, lamellæ parallel with these lines indicate polysynthetic twinning parallel to the base.

The diallagic augite is the first mineral in this rock to undergo decomposition.

* Rutley; The Study of Rocks, 1880, p. 125.

Two analyses of fresh material from the "Twins" separated by the Klein solution between the densities 3.105 and 3.29 gave the following results:

Analyses of Diallagic Augite.

	I.	II.	Mean.	Ratio.	
SiO_2	49.01	49.66	49.33	.822	.822
Al_2O_3	8.85	9.44	9.15	.089	.091
Fe_2O_3	none	.54	.27	.002	
FeO	9.05	9.05	9.05	.126	.783
MnO	trace	trace	----	---	
CaO	16.94	15.89	16.36	.292	
MgO	14.51	14.66	14.58	.365	
K_2O	.19	.19	.19	.002	.010
Na_2O	.55	.55	.55	.008	
Ignition	.25	.25	.25		
	99.35	100.23	99.73		

$RO : R_2O_3 : SiO_2 = 17 : 2 : 18.$

Characters of the Hypersthene.—Hypersthene is the most conspicuous mineral in the typical specimens of this rock. The grains, when isolated, are of a deep honey-yellow color. They are usually larger than those of the augite, and have a better defined outline. Under the microscope they are strongly pleochroic. Rays vibrating parallel to the brachydiagonal are brownish-red; those vibrating parallel to the macrodiagonal are yellow; those vibrating parallel to the vertical direction are green.

In thin sections this pleochroism is distinct but not so marked. When the sections are very thin it is quite feeble. The crystalline form is fairly well defined, but the edges are usually irregular, owing to penetration by the smaller crystals of feldspar. When cut parallel to the prismatic zone the crystals are two or three times longer in the direction of the vertical axis than in the other direction. The length rarely exceeds 4 mm., and is more frequently only about 2 mm. Sections perpendicular to the vertical axis show the prisms truncating the edges between the much more strongly developed pinacoids.

Cleavage parallel to the prism of about 92°, as well as cleavages parallel to the brachypinacoids and macropinacoids, can be seen in cross-sections of these crystals. Imperfect cleavage perpendicular to the vertical axis and others parallel to the terminal faces are seen in longitudinal sections.

The interference colors are low compared with those of augite.

The direction of extinction is parallel to the pinacoidal cleavages and diagonal to the prismatic. Hence all sections will extinguish parallel to the longitudinal direction of the crystals.

Sections which show yellow and green pleochroism give an acute bisectrix in converging light. Sections showing prismatic cleavage at right angles

give an obtuse bisectrix in converging light. Hence the optical character of the mineral is negative, since the vertical direction is that of least elasticity.

The inclosures so commonly found in massive hypersthene are entirely absent. The mineral has the same microstructure as the hypersthene which occurs in the porphyritic rocks. Well defined crystals of feldspar and grains of augite are nearly always inclosed in the hypersthene crystals. Bands of augite are sometimes intergrown with the hypersthene.

An intergrowth between hypersthene and a colorless mineral, which is probably plagioclase, exhibits granophyre structure in a section from the "Dumpling."

The material for the analyses I and II, given in the table below, was separated by the Klein solution at the density 3.356, after removal of the magnetite. The grains seemed to be fresh and pure when examined under the microscope.

Analyses of Hypersthene.

	I.—Twins.	*II.—Twins.*	*Mean.*	*Ratio.*		*III.—Buffalo Peaks.*
SiO_2	52.06	52.256	52.16	.886	.886	50.043
Al_2O_3	2.97	3.03	3.00	.030	.033	2.906
Fe_2O_3	0.26	0.64	0.45	.003		
FeO	15.16	15.16	15.16	.210	.868	17.812
MnO	0.37	0.35	0.36	.005		0.120
CaO	6.00	5.88	5.94	.106		6.696
MgO	21.82	21.96	21.89	.547		21.744
K_2O	0.04	0.04	0.04	.0004	.003	0.274
Na_2O	0.16	0.16	0.16	.0026		
Ignition	0.08	0.08	0.08			
	98.92	99.55	99.24			99.595

$RO : R_2O_3 : SiO_2 = 27 : 1 : 28.$

Upon comparing the analyses of the hypersthene from the "Twins" (I and II) with the analysis (III) by W. F. Hillebrand* of the hypersthene occurring in the hypersthene-andesites from Buffalo peaks, Colorado, it will be seen that the resemblance is as striking as that shown by the examination of thin sections.

Associated Minerals.—Biotite occurs in minute crystals here and there throughout the rock. Its outline is usually irregular, but occasionally angles of 120° were measured in basal sections. It occurs usually among the crystals of feldspar, either alone or surrounding magnetite. It may also be seen within the hypersthene and augite or along the edges of these minerals.

The apatite occurs inclosed in the feldspar or in the other minerals, having the form of fine needles.

*"On hypersthene-andesite," etc., by Whitman Cross: Bulletin U. S. Geol. Surv., no. 1, 1883, p. 29.

Quartz was noticed under the microscope in the rock from the "Dumpling" as isolated grains with fluid inclosures, and also intergrown with the feldspar, showing granophyre structure.

Green hornblende has been noticed in several sections.

Description of the Olivine-Hypersthene-Diabase.—This rock has a coarser grain, a more greasy luster and a darker color than the one described above. It weathers into globular masses. In thin sections the crystals of hypersthene are conspicuously larger than in the other rock, some of them measuring 6 mm. in length and 3 mm. in width. Olivine occurs quite abundantly as fresh crystals, with well defined outline, varying in size from 0.2 mm. to 4 mm. in diameter. Alteration has begun to take place along only the cracks. Biotite seems to be more common in this rock than in the hypersthene-diabase. The other constituents of the latter rock make their appearance here also, with perhaps the exception of quartz, which we have not observed.

The composition of this rock and its relations to the hypersthene-diabase as well as to a normal Mesozoic diabase from Connecticut are shown in the following analyses:

Chemical Analyses of Diabases.

	I.—Hypersthene-diabase.	*II.—Olivine-hypersthene-diabase.*	*III.—Diabase. West Roek, New Haven.*
	Sp. gr. = 3.09.	*Sp. gr.* = 3.10.	*Sp. gr.* = 3.03.
SiO_2	51.31	50.88	51.78
Al_2O_3	13.64	13.17	12.79
Fe_2O_3	0.52	1.11	3.59
FeO	8.49	9.66	8.25
MnO	trace	trace	0.44
CaO	12.41	10.19	10.70
MgO	12.73	13.05	7.63
K_2O	0.32	0.31	0.39
Na_2O	1.40	1.17	2.14
TiO_2	trace	----	1.41
P_2O_5	trace	----	0.14
Ignition	----	0.14	0.63
	100.82	99.67	99.89

The material chosen for analysis was perfectly fresh. The hypersthene-diabase (I) came from the quarry on the "Twins," in Culpeper county, Virginia. The olivine-hypersthene-diabase (II) came from a dike in the railroad cut not far from the "Twins."

We wish to call attention to the occurrence of hypersthene, a mineral rich in magnesia, in a diabase (I) which contains a large percentage of magnesia (12.73 per cent.) in contrast with the absence of this mineral in the normal diabase (III), which contains a very much smaller percentage of magnesia (7.63 per cent.). The olivine, together with hypersthene, also occurs here in

Paleozoic rocks, which rest at steep angles against a core of metamorphic gneisses and granites. At the base of the mountains are the seams of coal which form the chief source from which Montana's great mining and smelting industries must derive their supply of fuel. Unlike the lignites of the plains, these are true bituminous coals of excellent quality, and vary from dry steam coals to excellent coking varieties. These bituminous coals are all older than the lignites, and belong to two geological horizons: Those of Sand coulée, Deep creek and other localities in the vicinity of Great Falls, on the Missouri, have recently been determined by Professor J. S. Newberry to be of Kootanie age. In Montana the Kootanie rocks have not been found on the eastern slopes of the Rockies, save in the vicinity of Great Falls and in the Judith basin. Over half the entire coal product of the state is obtained from strata of later age, which are found in the two fields forming the subject of this paper.

The relative amounts of coal mined in the state in 1889, from the three geological horizons, were as follows:

Lignite	5,263 tons.
Later Cretaceous	191,138 "
Kootanie	166,480 "

These amounts will be exceeded during the present year (1890), but the figures will show quite as small a percentage of lignite mined, despite the wide range of this variety of coal throughout the state. So far as known, the bituminous coals are limited in their occurrence to the eastern and mountainous regions of the state.

Aside from the Kootanie coals of Great Falls, bituminous coals are known to occur only in the following fields: In the Upper Gallatin basin; near Virginia City; in the Cinnabar field on the Upper Yellowstone; in the so-called Bozeman coal field, and in its continuation eastward, the Rocky fork field.

The Cinnabar field was studied in some detail last summer, in connection with a geological examination of the region for the United States Geological Survey, in continuation of the geological survey of the Yellowstone National Park under Mr. Arnold Hague, and the identity of its coal-measures with those of the Bozeman field was established. The coal-bearing strata of the latter field were traced for a distance of about 100 miles.

THE CINNABAR COAL FIELD.

Location.—The small field known by this name is immediately north of the Yellowstone National Park, on the banks of the Yellowstone river. After leaving the deep cañons of the Yellowstone National Park, the Yel-

Slide. The following section shows the sequence of the beds from the coal-bearing strata down to the Carboniferous limestones (the same sequence being represented graphically in plate 13, figure 1):

The Cinnabar Section.

	Number of bed.	*Thickness in feet.*	
Laramie.	29	800	Sandstones, containing coal.
	28	5	Coal seam.
	27	125	Sandstones, white, massive, cross-bedded.
Colorado and Montana.	26	240	Fissile, argillaceous sandstones and shales.
	25	450	Shales, generally crumbly, with layers of black bituminous shale and harder sandy ledges.
	24	225	Shaly sandstones and limestones.
	23	40	Sandstone.
	22	165	Sandy, splintering, gray shales and limestones.
	21	500	Black bituminous shales.
	20	40	Limestone.
	19	400	Black shales, sometimes arenaceous.
	18	10	Sandstone.
	17	250	Black and dark-blue shales.
	16	15	Sandstone.
	15	75	Sandy shales.
	14	10	Sandstone.
	13	340	Thinly laminated arenaceous shales.
	12	15	Sandstones.
	11	75	Shales.
Dakota.	10	30	Quartzite.
	9	10	Limestone.
	8	150	Sandy shales.
	7	50	Red earthy limestones, magnesian.
	6	40	Conglomerate.
	5	95	Sandstone and shales.
	4	151	Sandstone.
Jurassic.	3	85	Red earths.
	2	20	Coarse, arenaceous limestones.
	1	160	"*Myacites* beds." Earthy, crumbling limestones.

The lowest beds in this section, designated as Jurassic, are earthy, crumbling limestones, characterized by numerous fossils, *Myacites subcompressa* being extremely abundant, together with many other forms common to the Rocky Mountain Jura, such as *Gryphæa*, *Pinna*, *Trigonia*, *Gervillia*, *Pentacrinus asteriscus*, etc.

Overlying these Jurassic shaly limestones is a hard ledge that is often a coarsely crystalline limestone, passing into sandstone and even into grits and conglomerates. It is characterized by an abundance of shell fragments, with many specimens of *Rhynchonella myrani*, *Camptonectes*, and other Jurassic forms. This horizon is very persistent, occurring wherever the Jurassic has been identified in the mountains of Montana, and forms a very useful datum plane in looking for the coal-bearing strata.

The conglomerate bed (number 6 of the section) undoubtedly represents the Dakota, but no fossils have been found either in it or in the transitional sandstones. Above this Dakota conglomerate there is a very persistent bed of limestone (number 9 of the section), which is distinguished by great numbers of small gasteropod shells, undoubtedly a fresh-water species, but as yet neither identified nor described. Above the limestone lies a bed of very dense quartzite (number 10), which has yielded no fossils.

In the shaly sandstones above the quartzite (number 12), specimens of the peculiar *Ostrea anomioides* have been found, both in this and in other localities. Above these shaly sandstones there is a series of beds which, in this section, are not like typical Fort Benton shales, but are harder and more sandy and include sandstone layers. Number 21 of the section is, however, a crumbly, black, bituminous shale, weathering down to a black earth, and these beds gradually pass into sandy shales, often rather hard, and weathering out as ledges. Where this series (numbers 21 to 26) is exposed in a cliff face, as is the case on the eastern side of the Electric-Cinnabar mountain ridge and in the cañon of Gardiner river, inside the national park boundary, they appear as leaden-gray, thinly bedded muddy limestones, with square jointing and numerous harder brown layers which sustain the vertical face of the cliff, the whole exhibiting the usual facies of the marine Cretaceous series. These beds form the sag south of Cinnabar mountain.

Above these muddy sandstones and shales there is an abrupt change in the sedimentation to creamy white, quite pure sandstones (numbers 27 to 29). The coal seams of workable thickness all occur in this series of very light-colored, cross-bedded sandstones, which aggregate some 600 feet in thickness. Although generally rather soft and sometimes loosely compacted rock easily crumbled between the fingers, these sandstones frequently form conspicuous bluffs, the underlying beds often weathering into steep and bare slopes capped by mural ledges of this sandrock series.

These coal-measure sandstones are very generally cross-bedded, while a predominating leafy structure is conspicuous on weathered surfaces, the rock splitting into plates of one-half or even one-quarter of an inch in thickness. This structure produces very picturesque forms of weathered ledges. Although the coal-measure series is generally sandy, there are thin belts of shale and clay associated with the many thin seams of coal.

The Coal-Measures and the Workings.—The accompanying figure 1 shows the number and relative position of the workable coal seams at the various openings in this field. As, however, the outcrops of the coal seams are always covered by débris and sand, it is impossible to obtain a perfect section showing all the seams.

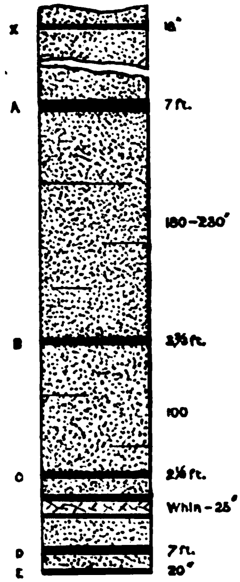


FIGURE 1—*Section of the Cretaceous Coal-Measures of the Cinnabar Coal Field.*

The sections made at the Horr and Craig mines show three workable seams, and it was noticed that while there is little doubt that the same seams of coal are worked at these two mines, yet the thickness of sandrock between them varies at the two localities. Careful measurements made in prospecting the field show that the thickness of sandstone between the two upper seams varies from 180 feet to 200 feet. At present, coal is mined at three localities, the Horr mine being the most important. The company controlling this mine own the extreme end of the Electric spur. The workings are all in faulted blocks, which was at first supposed to preclude the possibility of successful mining. A large block about a mile wide at the northern end of this ridge has been dropped some 600 feet by a fault, while the extreme end is formed of smaller blocks tilted at various angles. The coal is of excellent quality, however, and makes such fine coke that it has secured a ready market, and considerable mining has been done.

The oldest opening was in the lowest of the three workable seams, and was mined to the extent of 100 tons a day. A new tunnel is now worked in the northern part of the property, in the same seam, and a considerable output comes from a tunnel in the middle main seam (or *B*). The total output for 1889 was 22,400 tons. It was expected that the output for December (1890) would exceed 250 tons a day. The upper seam has not been mined as yet, though the outcrop has been opened at a few places to ascertain its character.

The present workings consist of the three tunnels mentioned, the coal being mined by the ordinary methods.

The sections represented in figure 2, taken at the ends of the tunnels at the different mines, show the character of the lower seam now worked.

The lowest seam (*E*, figure 1) found at the Horr workings is about one foot thick. Some 30 feet above it is the lower of the two seams now being worked. Above this seam the sandstone is broken by a layer of intrusive rock, called "whinstone" by the miners, which is about 10 feet thick. Three feet above this layer the baked shale carries fossil leaves. An examination

excellent and meets with a ready market, but the property must necessarily be limited by the fault, although the owner is convinced that the coal runs under the gneiss.

An incline follows the coal, which dips eastward at an angle of 40° at the surface, but becomes 60° some 100 feet below. At present this incline is 175 feet deep, and the seam is but little worked on the levels. The seam shows two to three feet of clean, brilliant coking coal, underlain by a thin parting, with a lower bench of bony coal that is not worked.

About 40 feet above this seam the outcrop of another large seam shows the following section:

Top coal	15	inches.
Fire-clay	4	"
Coal	30	"
Clay	½	"
Coal	3	"
Parting	¼	"
Bottom coal	4	"

An igneous rock similar to that found at the Horr mine occurs in the coal rocks on this side of the river, and is clearly intrusive, cutting across the beds.

A section of the beds on the southern side of Trail creek, at the Bowers mine, shows eleven seams of coal aggregating 21 feet; but only two of the seams can be worked. The following section shows the position of the veins:

Section of Coal-Measure Sandstone at the Bowers Mine.

Number of bed.	*Thickness in feet.*	
28	30	Massive sandrock, firm, light-gray.
27	½	Coal seam.
26	10	Sandstone, breaking into small angular fragments.
25	1	Shale, dark-gray.
24	6	Coal seam.
23	12	Shale, hard and slaty.
22	10	Sandstone, with shelly structure.
21	3	Coal; middle seam.
20	6	Red limestone, very magnesian.
19	3	Sandstone.
18	¾	Coal; called by the miners "upper bastard vein."
17	30	Sandstone, thinly fissile, brown.
16	¾	Coal.
15	10	Sandstone, shaly at top.
14	4	Coal.
13	20	Fissile and leafy sandstone.
12	30	Sandstone, massive, with jointed surfaces rounded.
11	6	Coal; poorly defined; vein 2 or 3 feet; the rest shale.
10	15	Sandstone, massive, brown, much pitted by weathering.
9	2	Coal.

Although the Cinnabar field is quite small and the coal-measures are scattered and broken, so that very extensive workings are not possible, yet as the measures yield an excellent quality of coal the portions now worked will no doubt be thoroughly exhausted before the field is abandoned.

THE BOZEMAN COAL FIELD.

Location, Extent, and General Geology.—Some 40 miles north of the Cinnabar coal field is the so-called Bozeman field, the best-known and longest-worked coal field of Montana. Although the coals of this field were known in 1871 and were examined by the geologists of the Hayden survey,* no exploitation was attempted until after the organization of the Northern Transcontinental survey, for whom Mr. George H. Eldridge† made a careful examination of the field, resulting in the purchase and working of the most promising portions at Timberline and Cokedale.

In its entire extent, the Bozeman coal field embraces the foot-hills lying at the northern base of the Boulder mountains and their continuation in the Snowy range westward to Livingston and over the Missouri–Yellowstone divide to Rocky cañon, where the outcrops swing around and occur at the eastern base of the Bridger range, having been traced northward some 25 miles. The field thus occupies the angle between the northerly trending Bridger mountains and the east-and-west range of the Snowy and Boulder mountains.

The general geological structure is that of a large synclinal basin whose southern and western borders are the mountains just mentioned. These ranges are formed of steeply upturned Mesozoic rocks, resting conformably upon Paleozoic limestones, which lie at a steep angle upon metamorphic gneisses. The chief feature of the region is a sharp folding of the sedimentary rocks, in general parallel to the line of contact with the Archean.

There is generally a strike fault, or its equivalent fold, running along the range before the beds flatten out toward the lower country on the north and east.

In the angle formed by the meeting of the Bridger mountains and the eastern ranges, this structure is disturbed by three sharp anticlinal folds, whose axes pitch steeply toward the north; so that while erosion has exposed the Carboniferous rocks on the ridges the productive (Mesozoic) coal-measures curve uninterruptedly around their ends. The western anticlinal is cut at right angles by the picturesque gorge of Rocky cañon, through which the Northern Pacific railway passes to the Gallatin valley. The larger streams issuing from the mountains, particularly the Yellowstone and

* 1st Ann. Rep. U. S. Geol. and Geog. Surv. Terr., 1871, p. 46; 2nd Ann. Rep., 1872, p. 113.
† Report 10th Census, vol. XV: Mining Industries, 1884, p. 739.

Cokedale Section.

	Number of bed.	*Thickness in feet.*	
Laramie.	38	3,000	Green and gray shales, with interbedded sandstone, poorly assorted.
	37	2,300	Sandstones of varying degrees of coarseness, poorly bedded, of volcanic material, the finer-grained layers like volcanic tuffs, carrying leaf remains.
	36	2,500	Sandstones and local beds of conglomerate; particles subangular, wholly of volcanic material.
	35	30	Conglomerate.
	34	140	Sandstone.
	33	2	Limestone.
	32	210	Sandstone.
	31	5	Coal.
	30	15	Shale.
	29	5	Coal.
	28	250	Sandstone; contains several seams of coal.
Colorado, Montana.	27	75	Massive sandstone; white, cross-bedded.
	26	150	Sandstone; "Tombstone" beds.
	23–25	1,150	Sandy shales and earthy limestones.
	22	25	Sandstone, forming prominent hog-back.
	21	300	Calcareous shales, muddy limestones and sandy shales.
	20	30	Sandstone, with conglomerate belt at top.
	17–19	630	Dark gray earthy shales, with sandy belt in center.
	11–16	765	Earthy gray and blue shales, with two sandy belts.
Dakota.	10	60	Quartzite.
	7– 9	250	Red, earthy magnesian limestones and fissile sandstones.
	6	35	Conglomerate.
Jurassic.	3– 5	150	Red earthy sandstones and shales.
	2	30	Limestones passing into sandstones and grits; Jurassic fossils.
	1	200	"*Myacites* beds." Limestones and shales.

The section is represented graphically and in greater detail in the diagram forming figure 2 in plate 13.

The uppermost beds of the section form the valley of Billman creek. The sandstones form bold combs and ledges, with intervening beds of very soft and crumbly green clays. A detailed section of these beds, or of the beds beneath, lying between them and the coals, is of comparatively little value, as the sandstones vary both vertically and laterally from fine-grained rocks, showing little evidence of bedding, to cross-bedded and rather friable sandstones, with local beds of conglomerate.

Beneath these beds lie sandstones (number 36), free from clays but of extreme variability, sometimes conglomeratic and often so fine-grained,

The Bozeman coals were placed provisionally in the Fort Pierre group by Professor Pumpelly in his report upon the coals of Montana.

Conclusion.

While the evidence presented in this paper is not considered conclusive, and while the work upon the district is not far enough advanced to warrant a final statement, yet is believed that the facts show that the coal-measures of the Cinnabar and Bozeman coal fields are probably of Laramie age, occurring at the very base of the Laramie series; and that they are conformably overlain by a totally different series of rocks, composed entirely of volcanic material and containing an abundant fossil flora of recognized Laramie types, in turn overlain by beds of fresh-water clays and sandstones of undetermined age, but belongiug to what has heretofore been considered as undoubtedly Laramie strata.

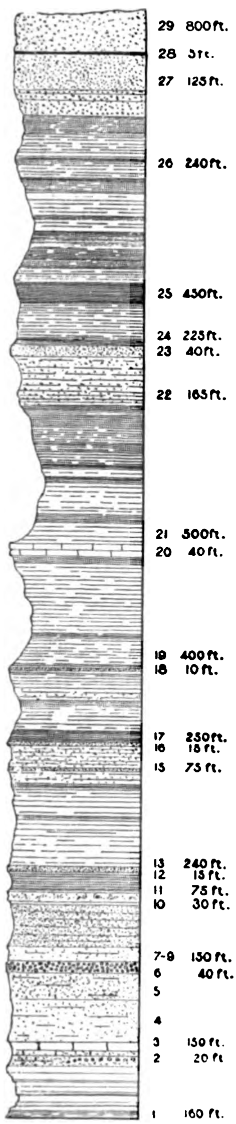


Figure 1, Cinnabar.

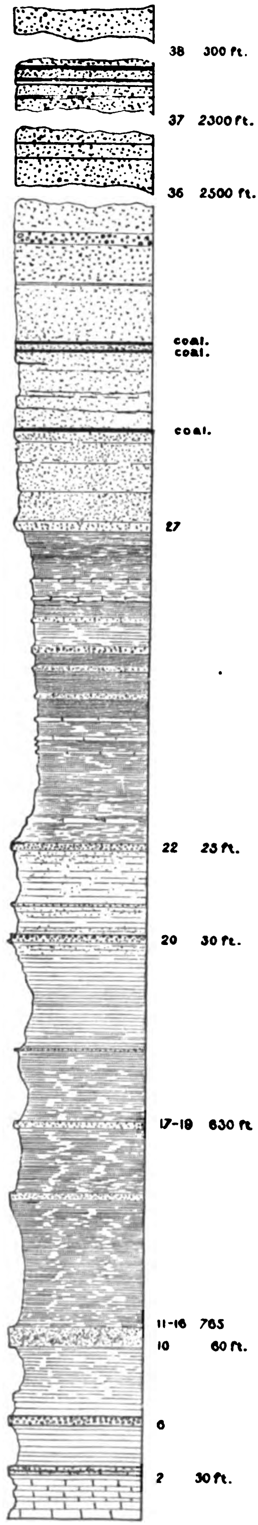


Figure 2, Cokedale.

Sections at Cinnabar and Cokedale, Montana.

[illegible]

Substituting (9) in (10) and reducing,

$$\frac{(2x^2 - r^2 + 1)r^2 - 4p^2x^2y^2}{4(x^2 - p^2y^2)} + \frac{(2y^2 - r^2 + 1)^2 - 4x^2y^2p^{-2}}{4p^{-2}(x^2 - p^2y^2)}$$

$$= k\left\{\frac{(2y^2 - 2xyp^{-1} - r^2 + 1)(2x^2 + 2pxy - r^2 + 1)}{-4p^{-1}(x^2 - p^2y^2)}\right.$$

$$\left. - \frac{(2x^2 - 2pxy - r^2 + 1)(2y^2 + 2xyp^{-1} - r^2 + 1)}{4p^{-1}(x^2 - p^2y^2)}\right. . \qquad (11)$$

Cancelling $4(x^2 - p^2y^2)$, clearing of fractions, and changing to polar coördinates, we have (since $2x^2 - r^2 = r^2(2\cos^2\varphi - 1) = r^2\cos 2\varphi$, and $2y^2 - r^2$ is similarly $-r^2\cos 2\varphi$, and $2xy = r^2\sin 2\varphi$),

$$(r^2\cos 2\varphi + 1)^2 - p^2r^4\sin^2 2\varphi - p^2(1 - r^2\cos 2\varphi)^2$$

$$+ r^4\sin^2 2\varphi = pk\Big[- \left(-r^2\cos 2\varphi - r^2\frac{\sin 2\varphi}{p}\right)$$

$$(1 + r^2\cos 2\varphi + pr^2\sin 2\varphi) - (1 + r^2\cos 2\varphi - pr^2\sin 2\varphi)$$

$$\left(1 - r^2\cos 2\varphi + \frac{r^2\sin 2\varphi}{p}\Big]\right. .$$

Arranging now according to powers of r, cancelling and putting 1 for $\sin^2 + \cos^2$—

$$r^4(1 - p^2) + 2r^2\cos 2\varphi(1 + p^2) - p^2 + 1 = 2pk(r^4 - 1);$$

or—

$$r^4 + 2r^2\cos 2\varphi\frac{1 + p^2}{1 - p^2 - 2kp} + \frac{1 - p^2 + 2pk}{1 - p^2 - 2pk} = 0; \qquad (12)$$

but since $p = \cot\frac{a}{2}$, according to Chauvenet (Trig. Eq., 142)—

$$\frac{1 + p^2}{p} = 2\csc a, \frac{1 - p^2}{p} = -2\cot a. \qquad (13)$$

Dividing the numerator and denominator of the coëfficients in (12) by p and substituting from (13) we have—

$$r^4 + 2r^2\cos 2\varphi\frac{2\csc a}{-2\cot a - 2k} + \frac{-2\cot a + 2k}{-2\cot a - 2k} = 0.$$

From this, replacing k by $\cot\beta$, we have (1).

For certain values of φ, equation (1) is much simplified, so that r and the

location of certain points of these curves are quite easily found. In fact we have, if—

$$\left.\begin{array}{lll}
\varphi = \pm\dfrac{\alpha}{2} & r^2 = \dfrac{\cot\alpha \pm \cot\beta}{\cot\alpha + \cot\beta} = \dfrac{\sin(\alpha-\beta)}{\sin(\alpha+\beta)}, \text{ or } 1; \\[2ex]
\varphi = 90^\circ \pm \dfrac{\alpha}{2} & r^2 = -\dfrac{\cot\alpha - \cot\beta}{\cot\alpha + \cot\beta} = -\dfrac{\sin(\alpha-\beta)}{\sin(\alpha+\beta)}; \\[2ex]
\varphi = 45^\circ & r^4 = -\dfrac{\cot\alpha - \cot\beta}{\cot\alpha + \cot\beta} = -\dfrac{\sin(\alpha-\beta)}{\sin(\alpha+\beta)}; \\[2ex]
\varphi = 0 & r^2 = \dfrac{\csc\alpha + \csc\beta}{\cot\alpha + \cot\beta} = \dfrac{\frac{\cos}{\sin}\,\frac{1}{2}(\alpha-\beta)}{\frac{\cos}{\sin}\,\frac{1}{2}(\alpha+\beta)}; \\[3ex]
\varphi = 90^\circ & r^2 = -\dfrac{\csc\alpha \pm \csc\beta}{\cot\alpha + \cot\beta} = \dfrac{\frac{\cos}{\sin}\,\frac{1}{2}(\alpha-\beta)}{\frac{\cos}{\sin}\,\frac{1}{2}(\alpha+\beta)}.
\end{array}\right\} \qquad (14)$$

Moreover, these curves cut the axes in general at right angles while they cut the primitive at an angle β; so that, when the points for the above radii are plotted, the curves are not difficult to sketch.

The projection used in figure 6 gives the highest degree of symmetry to the curves, and for the radii noted in (14) φ and β enter so symmetrically that solutions for one octant answer with slight modifications for other octants and interchanged α and β.

Probable Difference between solid Angles and their Traces.

§ 5. The probability that a given solid angle, P_1CP_2, will be cut to give a certain plane angle is indicated in figure 6 by the area between successive curves. Thus a glance at figure 6 gives us some idea of the various probabilities. We must remember, however, that the bounding planes of a mineral cannot be cut very obliquely if they give a well-defined and easily noticed outline. The same holds true of the development of cleavage cracks: but it does not hold true for twinning lines, since in this case sharp interference bands appear along the line of juxtaposition of two twins when they are placed between crossed Nicols.

The breadth of the border (b) made by a plane (P_1) depends on the thickness of the thin section (d) and on the angle at which it is cut (SP_1). The formula is—

$$b = d \cot SP_1.$$

By writing $\varphi - \varphi_1$ for φ we can refer φ to any initial line, and if we have a similar equation derived from C, S, and P_2 we can eliminate r and have an equation of the fourth degree to determine φ. This I have already obtained.* If, in figure 3, φ is measured from O_3C, the bisectrix of P_1CP_2; if $a_1 = CP_1$, $a_2 = CP_2$, $\varphi_1 = \frac{1}{2} < P_1CP_2$, $n = cot < SC : SP_2$, and $m = cot < SC : SP_1$, then φ is determined by the following equations:

$$tan\,\varphi = -\frac{A\,cos\,\theta + B}{C\,cos\,\theta + D}, \text{ and } sin\,\theta = -\frac{E\,sin\,\varphi\,cos\,\varphi + F}{A\,cos\,\varphi + C\,sin\,\varphi}; \quad (5)$$

or—

$$tan^4\,\varphi\,(F^2 + D^2 - C^2) + tan^2\,\varphi\,(2\,F^2 + D^2 - C^2 + B^2 - A^2 + E^2) + B^2 - A^2 + F^2 + 2\,(tan^3\,\varphi + tan\,\varphi)\,(DB + EF - AC) = 0,$$

where—

$$\begin{aligned} A &= -\,cos\,\varphi_1\,(cot\,a_1 - cot\,a_2); \\ B &= -\,sin\,\varphi_1\,(n\,cot\,a_1 + m\,cot\,a_2); \\ C &= \,sin\,\varphi_1\,(cot\,a_1 + cot\,a_2); \\ D &= -\,cos\,\varphi_1\,(n\,cot\,a_1 - m\,cot\,a_2); \\ E &= \,m - n;\text{ and} \\ F &= -\,sin\,\varphi_1\,cos\,\varphi_1. \end{aligned}$$

Application to Augite, etc.

§ 7. There is one most frequent case that we may consider in detail: It arises when one of the three planes whose traces are supposed to be seen bisects the angle between the other two. This occurs in hornblende, augite, olivine, feldspar, titanite, pyrite and other minerals. It may be treated by either construction; and equation (5) of § 6 takes the much simpler form—

$$cos\,2\,\varphi = a + b \pm \sqrt{(a + b + 1)^2 - 4\,b}, \quad (1)$$

where—

$$a = \left(\frac{n + m}{n - m}\,cot\,a\right)^2 \text{ and } b = \left(\frac{2}{n - m}\,cot\,a\right)^2.$$

We have also—

$$b\,(1 - cos\,2\,\theta) = 1 + cos\,2\,\varphi. \quad (2)$$

We derive (1) from (5) of § 6 as follows: $cos\,a_1 = 0$, $sin\,\varphi_1 = -1$, $cot\,\varphi^1 = cot\,a_2$; and we may drop the subscripts and write $cot\,a$ for both. Therefore,

* Tschermak's Min. u. Pet. Mitth., October, 1887, p. 207.

$A = D = F = 0$; $B = (n + m) \cot a$; $C = -2 \cot a$; and $E = m - n$. Hence, from § 6—

$$\tan \varphi = \frac{-B}{C \cos \theta}, \sin \theta = \frac{-E \cos \varphi}{C}. \tag{3}$$

Since $\sin^2 \theta + \cos^2 \theta = 1$, we have—

$$B^2 \cot^2 \varphi + E^2 \cos^2 \varphi = C^2. \tag{4}$$

Now we can put $a = \left(\frac{B}{E}\right)^2$ and $b = \left(\frac{C}{E}\right)^2$, and we may call $\cos^2 \varphi = x$, i. e., $\cot^2 \varphi = \frac{x}{1 - x}$. Accordingly—

$$\frac{ax}{1 - x} + x = b; \tag{5}$$

whence—

$$x = \frac{a + b + 1}{2} \pm \sqrt{\left(\frac{a + b + 1}{2}\right)^2 - b}. \tag{6}$$

But as $x = \cos^2 \varphi = \frac{1 + \cos 2 \varphi}{2}$, equation (1) follows at once from (6). We may develop it into a rapidly converging series. Moreover, putting b in equation (3) we have $\sin^2 \theta = \frac{\cos^2 \varphi}{b}$. Substituting 2θ and 2φ for θ and φ, we obtain (2).

In number* 909, for example, there is an augite twin, quite obliquely cut, which is sketched in figure 2*a*. From it we have the following data: The trace of twinning (100) is parallel to the vertical cross-hair when the rotating stage is at 7°.1. Similarly for the trace of $(1\bar{1}0)$ we have 340.°9; for (110), 63°.1. Hence $n = \cot 26°.2 = -2.0323$, and $m = \cot 56°.0 = 0.6745$, and we have the following solution:

$$\cot a = \cot 46° 27'; \ \log. \cot a = 9.9780$$
$$m - n = 2.7068; \ \log. m - n = 0.4324$$
$$\text{Subtract} \quad 9.5456 \times 2 = 9.0912;$$

$$m + n = -1.3578; \ \log. m + n = n\, 0.1328$$
$$\text{Add to the above:} \quad n\, 9.6784 \times 2 = 9.3568.$$

$$\text{Log.}^{-1}\, 9.0912 = 0.1234; \ \log.^{-1}\, 9.3568 = 0.2274 = a.$$

Multiply 0.1234 by 4, and we have $0.4936 = b$.

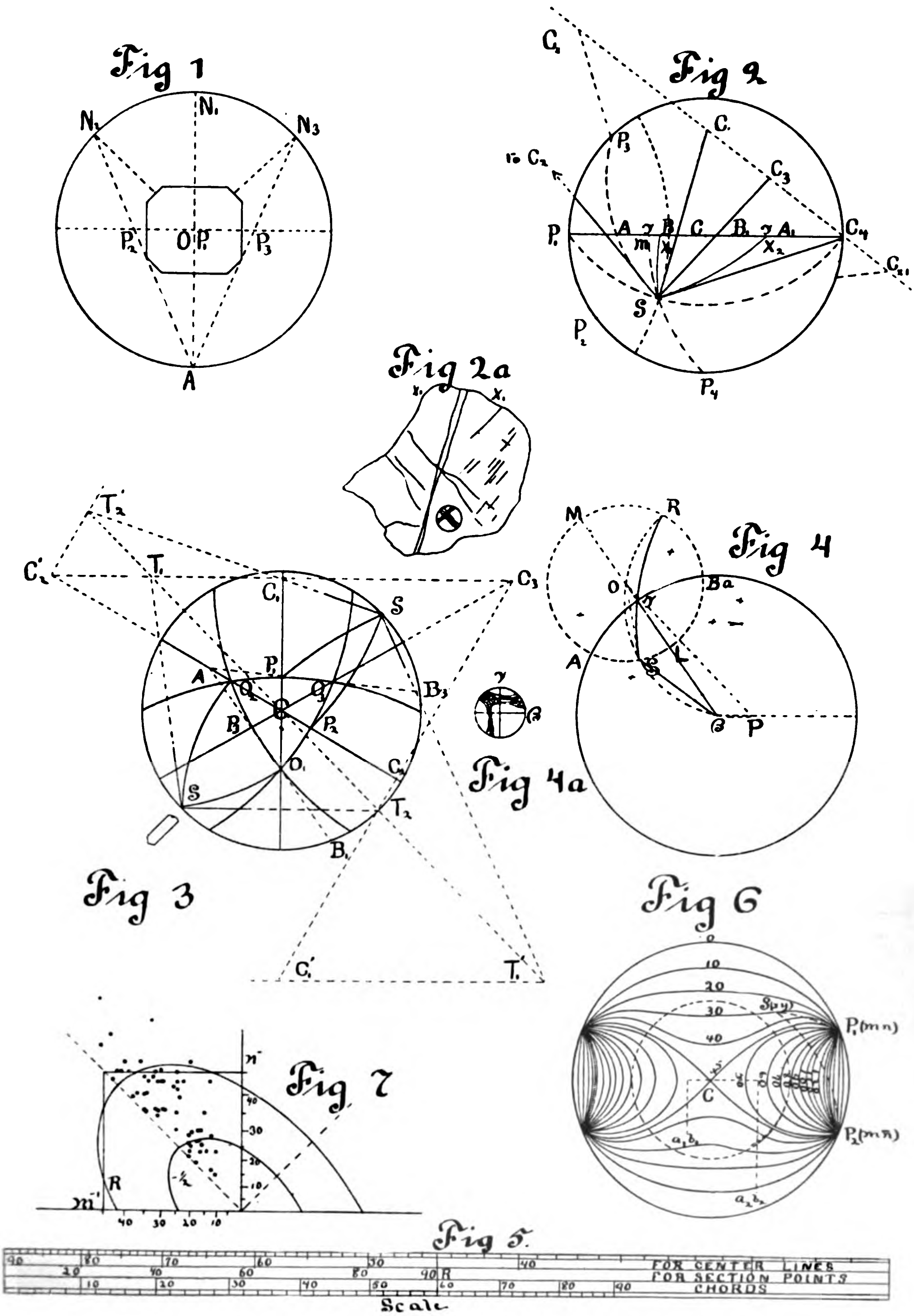
* The numbers refer to sections in the collections of the Michigan State Geological Survey.

[illegible]

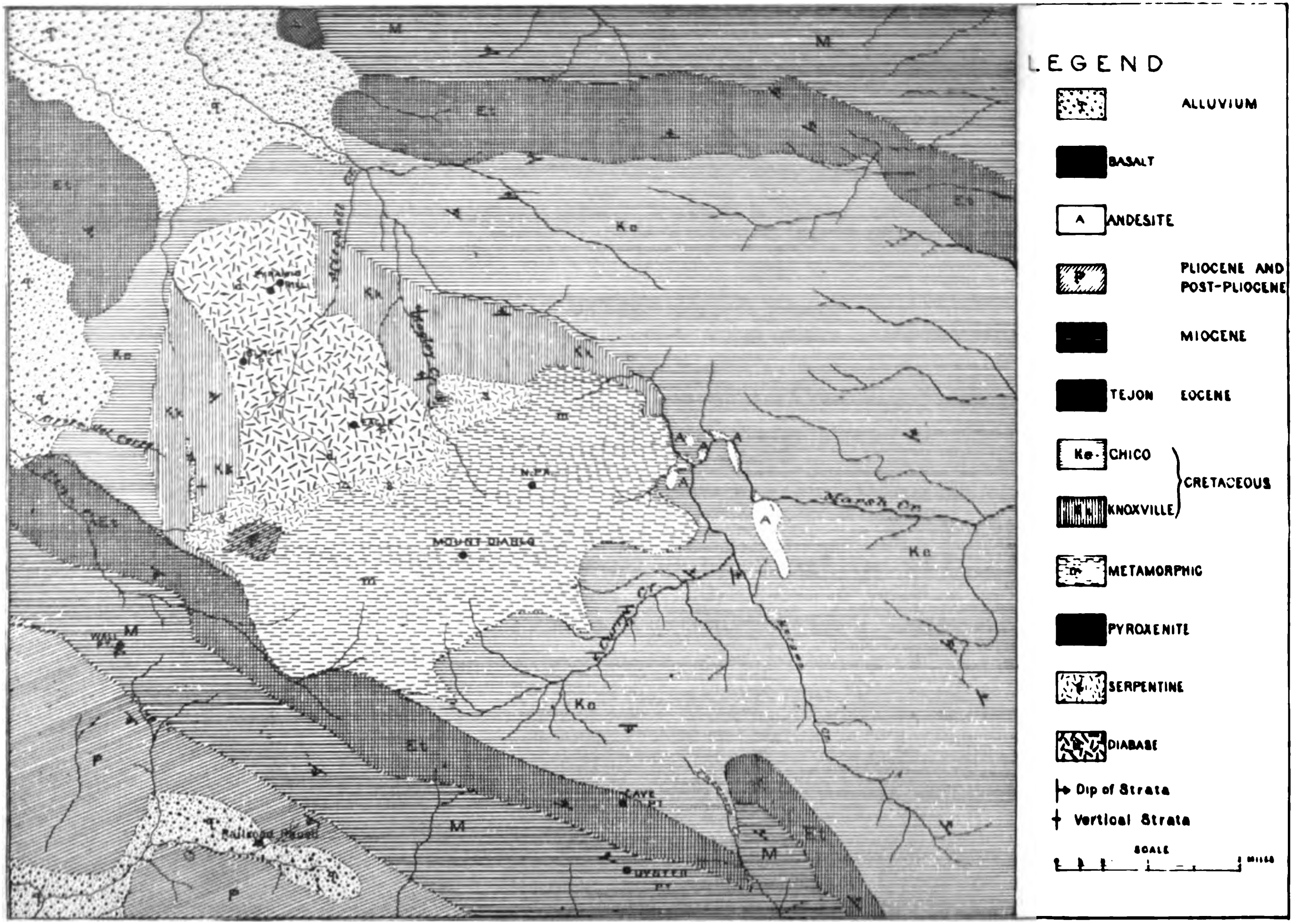
[illegible] Dana's Textbook, page [illegible]

[illegible]

[illegible] will give a different ellipse [illegible]. Now, we remember that m^{-1} is [illegible] the basis to the trace of P_r, or,



Diagrams used in identifying Mineral Crystals.



GEOLOGIC MAP OF THE VICINITY OF MOUNT DIABLO, CALIFORNIA.

blende, irregular portions are nearly colorless, extinguishing, however, simultaneously with the brown parts.

Professor G. H. Williams* has described compact greenish hornblende from the Baltimore gabbro area, regarding it as a secondary product of the diallage, it being intimately associated with fibrous hornblende of undoubtedly secondary character. In another paper † he points out that it has long been recognized and experimentally proved by Mitscherlich and Berthier, G Rose, and Fouqué and Lévy that pyroxene and hornblende are two crystallographic forms for the same molecule, of which the former is stable at high and the latter at low temperatures; and he gives evidence of the alteration of hypersthene to compact brown hornblende.

Professor R. D. Irving concludes that the compact brown basaltic hornblende in certain hornblende-gabbro rocks of the Lake Superior region results from the alteration of pyroxene.

It may well be, therefore, that all of the hornblende of the diabase-diorite, even when compact and brown in color, is the result of paramorphism from pyroxene.

All of the slides described above exhibit the same ophitic structure, and the entire area is believed to have been originally diabase. Associated with the diabase-diorite there is an aphanitic black rock, found in small amount only. It has been collected on the southern flank of Black point and on the southeastern side of Pyramid hill. While one would infer from some hand specimens, showing the fine-grained rock and the diorite in contact, that it must occur as dikes in the diorite, a study of an exposure on the southeastern slope of Pyramid hill did not lead to this conclusion; the rock occurring there in small bunches and, apparently at least, grading into the coarser rock. Number 286 is a specimen of this aphanitic black rock. It is composed of lath-like plagioclase and flecks of fibrous green hornblende imbedded in a fine ground-mass of feldspar microlites and grains of magnetite. The latter is very abundant, and doubtless gives the black color to the rock. The feldspar phenocrysts are of notable size.

On page 412 of the supplement to this paper will be found two analyses of specimens from the diabase area by Dr. Melville. Number 44 is a diabase-diorite, and number 43 is one of the diabases above described. It will be observed that the two analyses are remarkably alike, and also that they do not differ materially from the analyses of Mr. Becker's pseudodiabase.‡ It may be noted that the composition of the glaucophane schist (supplement, page 413) is very similar to that of the diabase.

Peridotite and Pyroxenite.—Another large mass of crystalline rock, apparently also eruptive, lies south of the diabase area just described. It is

* Bulletin 28, U. S. Geol. Surv., 1886, pp. 40-42.
† Am. Jour. Sci., 3d ser., vol. XXVIII, 1884, p. 262.
‡ "Quicksilver Deposits," pp. 98, 99.

comparatively rare may be seen by referring to J. D. Dana's "Manual of mineralogy."

The dike nature of this serpentine area is best shown on the western side of the mountain east of the eastern fork of Pine creek, where it is cut across by the Arroyo del Cerro and its branches. It is here from a few feet to about 150 feet in width, enclosed in dark, calcareous shales containing, at several points near the serpentine, *Aucella mosquensis*, Von Buch, a fossil characteristic of the Knoxville beds (lower Cretaceous); and near the northern end of this narrow dike both *Aucella* and *Belemnites* occur in limestone.

The strike and dip of the dike is in general about that of the enclosing shales, the strike being nearly north-and-south, and the dip about vertical. The serpentine of this narrow dike has an imperfect fissile structure, and at one point only did I find the dark bastitic variety.

The eruptive serpentine of Mount Diablo does not differ materially in chemical composition from the metamorphic serpentine described by Becker.* A specimen from one of the small serpentine areas on the southern slope of the mountain contains abundant remains of pyroxenes and olivines. The area is thought to have an origin similar to that of the large serpentine dike on the northern slope above described.†

As to the diabase and serpentine occurring in little patches throughout the metamorphic areas of the Coast ranges of California, and mixed in the most confusing manner with unquestionably clastic rocks of early Cretaceous age, it might be held by one seeking to prove their igneous origin that a molten magma injected into a mass of rocks so thoroughly and irregularly fractured as are the rocks of the metamorphic areas would on consolidation form irregular areas rather than definite areas and dikes, there being few regular fissures into which a molten magma could be injected. This is shown likewise in the irregular and generally non-continuous character of the quartz veins of the Coast ranges, giving positive testimony as to the character of the fissures which they have filled. Professor Whitney says: ‡

"The rocks of the Coast mountains are especially distinguished by the fact that the movements to which they have been subjected, and which have originated the complex of alternating elevations and depressions making up the system of chains known as the Coast ranges, have been apparently sudden and sharp, so that the result may be called a crushing and breaking rather than an uplifting and folding. * * * Often, and especially in the central and northern portions of the state, the rocks for long distances are so broken up that a recognition of their real structural relations is entirely impossible."

In marked contrast to these are the fissures of the Sierra Nevada, contin-

*Quicksilver Deposits, 1888, p. 110-111.

†Mr. G. P. Merrill has called my attention to a serpentine collected by himself at San Francisco (the area that extends out to Fort Point), in a slide of which pyroxenes and olivines are plainly to be noted.

‡Auriferous Gravels of the Sierra Nevada, 1880, p. 16.

Cinnabar occurs here, at the contact of the andesite with the adjacent unaltered shale. It is associated with chalcopyrite and calcite, some of the cinnabar being so intermingled with the calcite as to indicate contemporaneous deposition. There is no quartz at this place. Solfataric action is still going on in the old tunnel run in for cinnabar.

At a point about one mile south of the main peak there is a vein of quartz, much stained by ferric oxide. In samples of this, Dr. Melville found cinnabar in considerable quantity.

Coal.—Extensive beds of coal occur in strata of Tejon age, about five miles northeast of the main peak. These deposits have been successfully mined for many years. The coal is rather friable, and inferior to that of Bellingham bay and other more northern localities. On the dumps of some of the old mines (Black Diamond and others) there are abundant pieces of carbonized wood, usually containing pyrite.

There are also some coal seams, that will sooner or later be worked, about two and a half miles southwest of the main peak, by Pine creek, in strata of the Tejon, which is the usual coal-bearing formation of central California. Coal of a poor quality is obtained, however, from nearly horizontal beds of Pliocene age, at Ione, Amador county, California, and at some other points.

Numerous coal seams occur in the neighborhood of Corral hollow pass, southeast of Livermore. The strata are considerably faulted, and in consequence the miners find difficulty in following the coal seams. The seams dip at a high angle, and the coal is sometimes decomposed to a depth of fifty or more feet by the action of surface waters, the resulting material being a rust-colored spongy mass, which no one not familiar with coal prospecting would suppose to indicate the presence of coal seams.

According to Mr. J. Richards, who kindly showed me about the mines, the coal above water-level contains much gypsum, but below the water line the sulphate of lime is in solution in the water and the coal is in consequence of better quality. I myself noted some gypsum in the coal. At the time of my visit (1886) there were no producing mines, but the coal seams were well exposed at the Livermore, Richards and Coleman mines. At the latter mine there was exposed a vein about five feet thick, dipping 80° northwestward. Stratigraphically above the coal seam, in a shaly stratum, were numerous oyster shells.

In the Richards coal mine the coal seam, where observed, dips 35° northwestward, and the coal was decomposed down eighty feet, following the vein.

On the surface near the Richards mine, in sandstone, I collected Tejon fossils (*Turritella uvasana*, and others).

At the present time (1890) some of these coal deposits are worked.

Mineral Springs.—Besides the springs referred to in connection with the quicksilver mine, mineral waters issue at several points. A warm spring which I have not seen is said to exist in Mitchell cañon.

The Knoxville Beds.—These beds are, as usual, associated with the metamorphic rocks, and the previously described pre-Tertiary igneous rocks are intruded in them. This statement may be taken with some reservation in regard to the diabase area, which is practically a *massif;* but the peridotite (serpentine) penetrates the Knoxville shales, forming a narrow dike a mile long.

The rocks of this age consist almost universally of dark shales with occasional arenaceous and calcareous layers. Each calcareous layer is rather a series of lenticular bodies than a continuous limestone stratum. This applies to the Sierra Nevada as well, only there the limestone masses are hundreds of feet in diameter. At Mount Diablo these lenticular masses do not exceed twenty feet in width, measuring across the strike. It is mostly in the calcareous strata that fossils are to be found. Besides the molluscan remains, they contain elasmobranch teeth and spines and numerous minute tests of foraminifera. These tests have in some cases undergone silicification. The most characteristic fossil of the Knoxville beds is *Aucella.* The slender variety, *Aucella mosquensis,* Von Buch, occurs, as before stated, in Bagley cañon, about two miles north of the main peak; also on the eastern side of the creek that heads east of Eagle point and eight-tenths of a mile northeast of that peak; also at several points in the neighborhood of the peridotite dike that lies two miles west of Eagle point; and about one-third of a mile and again one mile southwestward from the summit of Black point.

Belemnites occurs near the northern end of this peridotite dike in limestone, and also in a coarse sandstone just east of the limestone. In this sandstone there are calcareous pebble-like nodules, the *Belemnites* occurring in the sandstone itself.

I observed near the mining camp of Knoxville, in Napa county, California, some croppings similar to these, in which *Belemnites* is to be found in the sandy matrix, the included limestone pebbles containing *Aucella mosquensis,* Von Buch.

About one-third of a mile north of the *Belemnites* limestone I found in a single calcareous nodule *Aucella, Inoceramus,* and two small gasteropods. This is, I think, the first time that *Inoceramus* has been noted in the Knoxville beds in California.

In a limestone nodule in strata of the Knoxville group, about one and seven-tenths miles southwestward from Eagle point, just north of the serpentine dike, I collected a fragment of wood of which a thin section was made and referred to Mr. F. H. Knowlton, who states that it belongs to the genus *Cupressinoxylon.* This genus, I understand him to say, is regarded as the ancestor of the sequoias. Near the fossil wood I found a specimen of *Aucella mosquensis.*

The dip and strike of the Knoxville strata are usually quite variable, but the dip is universally great, and the strata are frequently vertical.

c. Shaly gabbro, bearing carbonates and sulphates; it is friable, light green, resinous, and possesses a tendency to fibrous structure. Macroscopically, it looks like a true serpentine.

d. Crystalline gabbro, apparently eruptive, taken at the exact contact with the preceding specimen; it is hard, very compact; small pearly cleavage planes, with striations, are well marked; the color is dark green.

These specimens were taken within the space of a foot, and in the order tabulated.

Series I—Analyses of Shales and Gabbros from Bagley Cañon.

	*(9) *a*	(173) *b*	(174) *c*	(175) *d*
H_2O at 105° C.	3.01	2.41	2.29	1.20
H_2O above 105°	5.92	2.74	2.47	1.83
CO_2	----	2.35	1.89	——
SO_3	0.93	0.24	0.43	----
SiO_2	56.66	45.43	45.69	47.49
P_2O_5	0.15	0.04	0.06	trace
Al_2O_3	17.64	12.55	18.30	15.81
Fe_2O_3	0.49	----	1.85	1.07
FeO	5.22	6.50	4.72	4.50
NiO	----	----	----	0.06
MnO	0.19	0.21	0.24	0.41
CaO	1.67	12.39	13.50	15.53
MgO	3.50	13.41	13.06	10.39
Na_2O	2.17	1.71	1.36	1.16
K_2O	2.27	0.11	trace	trace
Organic matter	little	little	---	----
	99.82	100.09	100.86	99.45

If these examples are to be regarded as illustrating the passage of one extreme of the series into the other, as there is some evidence, then the cause of this metamorphosis is to be found in the action of solfataric waters. The presence of sulphates and carbonates in specimens *a*, *b* and *c* becomes an important point, as tending to the confirmation of this assumption. The waters at present contain sulphates, carbonates and chlorides of the alkalies and of calcium and magnesium, together with a little silica, iron, carbonic acid and sulphuretted hydrogen. A less hydrated substance, the gabbro, is formed, and by the action of the heated waters calcium and magnesium oxides are added at the same time that a quantity of silica, alumina and alkalies are leached out. The sudden jump between specimens *a* and *b* in the contents of lime and magnesia must be explained on the supposition of a very rapid and

* Numbers in parentheses indicate the office labels of the working collection.

a. Shale, altered considerably, light-brown and friable. Carbonates in small quantity form a part of the mass of the rock. This shale is Neocomian.

b. Serpentine, very much weathered, interwoven with seams of quartz and calcite; darker colored than *a*; fibrous tendency slight.

c. Limestone, weathered, very friable, light slate-colored.

d. Calcareous shale, next to the same serpentine dike mentioned in connection with series III. It is hard, compact, dark-colored; it contains seams of calcite, but the analysis was made on material from which this secondary carbonate had been almost completely removed. In the quartz seams a zeolite (natrolite) occurs, and sparingly distributed small particles of pyrite are to be found. The shale is very much altered, particularly at the contact.

e. A yellowish-green talc-like rock, forming a part of the serpentine dike at this point and containing considerable chromite. It has a resinous luster, and a tendency to fibrous structure. Limestone intervenes between this rock and the calcareous shale *d*.

Specimens *c*, *d*, and *e* properly belong to a separate series, of which *c* and *e* are extremes. They are grouped here for convenience.

Series IV—Analyses of Specimens from near Arroyo del Cerro.

	(233)	(235)	(236)	(238)	(239)
	a	*b*	*c*	*d*	*e*
H_2O at 100° C.	8.74	3.32	0.76	1.41	0.44
H_2O above 100° C.		12.51	2.33	6.24	12.40
SiO_2	45.64	41.52	21.19	44.56	32.27
CO_2	4.59	----	26.84	17.62	----
P_2O_5	0.27	----	2.55	0.16	trace
Cr_2O_3	0.12	----	----	----	5.19
Al_2O_3	15.42	1.57	0.39	3.12	11.45
Fe_2O_3	3.40	3.50	1.52	1.27	trace
FeO	3.73	1.07	undet.	5.21	5.05
NiO	----	----	----	----	0.19
MnO	0.33	0.29	3.61	trace	trace
MgO	4.62	36.84	1.39	3.39	33.30
CaO	8.11	0.44	35.61	12.70	0.41
Na_2O	3.13	----	undet.	3.09	trace
K_2O	1.86	----	undet.	0.88	trace
	99.96	101.06	96.19	99.65	100.70

Series IV shows a contact of shale *a* with serpentine *b*, the analyses of which are given in the above table. A transition is also given of limestone *c*,

Series VI—Analyses of Tertiary and Cretaceous Sandstones.

	(11) *a*	(187) *b*	(59) *c*	(33) *d*
H_2O at 100° C.	1.06	1.45	1.43	0.57
H_2O above 100° C.	2.60	3.34	2.25	3.45
CO_2	none	5.10	7.76	*11.30
SiO_2	73.71	56.84	44.54	36.93
P_2O_5	none	0.10	0.29	0.16
Al_2O_3	10.40	11.37	12.63	7.22
Fe_2O_3	3.89	1.46	2.50	1.59
FeO	1.88	4.95	3.08	2.95
MnO	0.17	0.22	0.44	0.57
CaO	0.96	7.62	14.65	29.34
MgO	1.62	3.10	5.55	2.34
Na_2O	3.48	3.26	3.35	2.94
K_2O	0.99	0.86	1.37	0.64
	100.77	99.67	99.84	100.00

Series VII.—From the diabase area in Mitchell cañon, north of the serpentine dike, two specimens were selected. Specimen *a* was fresh, but specimen *b* was somewhat altered and partly uralitic. The analyses show but slight differences in composition. In this diabase serpentine is absent, and it is not found to yield this hydrous magnesian silicate. It would be necessary to substitute a magnesian silicate for the plagioclase, which has been shown before in the case of shales a difficult and an imperfect operation. Field observations show no relations between the diabase and the serpentine of Mount Diablo as they have shown between the pyroxenite and serpentine.

Series VII—Analyses of Diabase from Mitchell Cañon.

	(43) *a*	(44) *b*
Loss at 105° C.	0.59	0.34
Loss above 105° C.	2.90	2.67
SiO_2	52.06	51.58
P_2O_5	0.13	0.24
TiO_2	0.47	1.05
Al_2O_3	14.34	14.99
Fe_2O_3	2.11	2.04
FeO	7.74	8.36
MnO	trace	trace
CaO	8.05	8.59
MgO	9.26	6.51
Na_2O	1.74	3.08
K_2O	0.73	0.31
	100.12	99.76

* CO_2 by difference. Organic matter in very small quantity exists in all four sandstones, but it was not determined.

The original extent of the complete formation beyond its present boundaries is not known. It may have been many miles broader than it now is, but there is no good evidence now in hand on this question.

Formation of the Trap Sheets.—During the period of deposition there were outflows of lava at several dates. The sheets formed by outbursts at three of these dates are now well correlated; the first of them is relatively thin and vesicular or amygdaloidal; the second is much thicker and more massive, and at some places it appears as a double flow, one sheet of lava lying on another without a noticeable accumulation of sediments between them; the third is again thin like the first. The outcropping edge of the massive middle sheet now forms a series of strong ridges; hence it was called the "main" trap sheet by Percival, while the lower and upper were called the

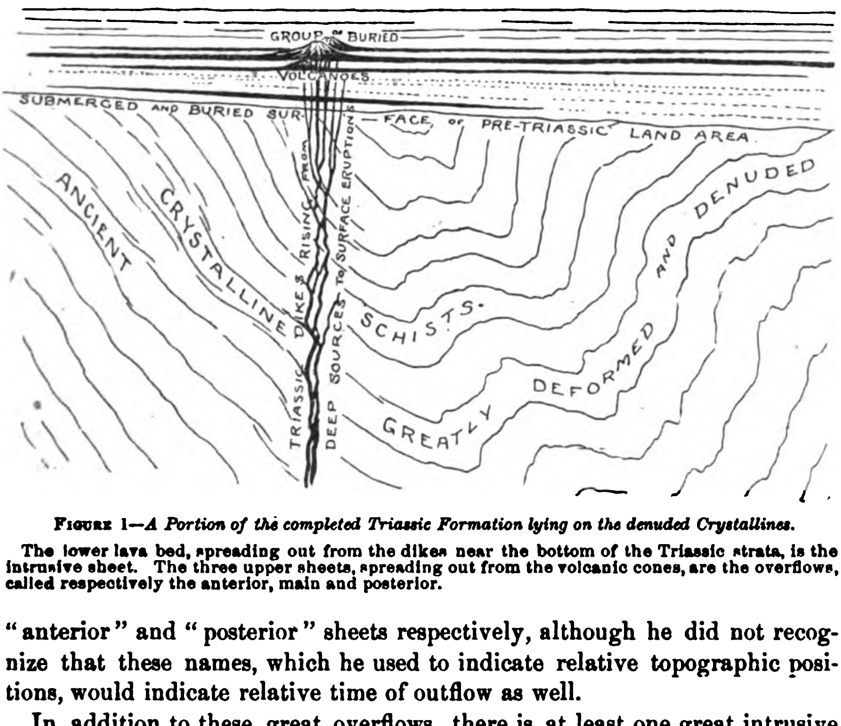


Figure 1—*A Portion of the completed Triassic Formation lying on the denuded Crystallines.*

The lower lava bed, spreading out from the dikes near the bottom of the Triassic strata, is the intrusive sheet. The three upper sheets, spreading out from the volcanic cones, are the overflows, called respectively the anterior, main and posterior.

"anterior" and "posterior" sheets respectively, although he did not recognize that these names, which he used to indicate relative topographic positions, would indicate relative time of outflow as well.

In addition to these great overflows, there is at least one great intrusive sheet* and, apparently, several smaller ones. The large one occurs close to the base of the formation, and hence is now seen near its western margin, because the present structure is, as a whole, an eastward-dipping monocline. The date of this intrusion is not definitely fixed, although it appears that

* Professor Newberry has misquoted me (Monograph XIV, U. S. Geol. Survey, 1888, p. 7) as saying that all the trap sheets were overflows. The intrusive nature of the West rock and palisade sheets was recognized in my first essay, and I have never found reason to regard it as of other origin.

Standing on one of its summits, such as Chauncey peak or Higby mountain, three miles northeast of Meriden, one may see the crest-lines of the main ridge in the various blocks toward the northwest and southeast, all reaching about the same height, and this common height closely like that of the remarkably even sky-line of the crystalline plateau by which the Triassic lowland valley is enclosed on the east and west. The gradual descent of the highland to the south is also apparent from this point of view. Another notable feature seen at the same time is Mount Carmel, apparently in the same block with Higby, but some ten miles toward the southwest, rising somewhat above the sky-line of the crystalline highland, and, therefore, to be regarded as having been a low hill on the old peneplain in Cretaceous time.

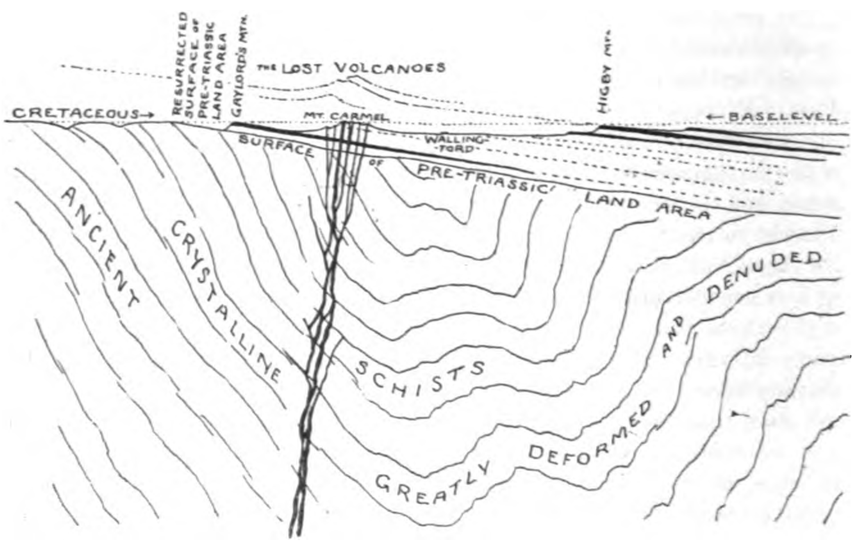


FIGURE 2—*A Portion of the Triassic Formation, after tilting into the monoclinal Attitude and deep Erosion.*

The volcanic cones inferred to have been formed where the lavas rose to the surface and supplied the overflows are now all destroyed, and Mount Carmel is supposed stand beneath their ancient site, where the feeding dikes now outcrop. No faults are shown in this figure, because the section line is supposed to run between the enclosing faults of a single block; and no cross-faults are yet known.

It has been stated above that as Mount Carmel is composed of numerous dikes, many of large size, it may be regarded as the locus of the volcanic pipes up through which rose the lavas now seen in the extrusive and intrusive sheets. No direct evidence of this correlation can be obtained at present; for the intrusive sheet near the base of the formation would intersect the Mount Carmel dikes below the actual surface of the country, and the extrusive sheets would rise far above Mount Carmel, if prolonged in its direc-

points. The extreme points now identified in this bed are about fifteen miles apart, and ten well proved faults occur between them.

Another bed of dark shales with impressions of fish and plants has been known for many years in a small brook north of the village of Westfield, Connecticut, and about half a mile southwest from the station of that name on the Berlin-Middletown branch of the New York, New Haven and Hartford railroad. This lies about one hundred and fifty feet below the posterior trap sheet, or about a quarter way from the posterior to the main sheet. It will be referred to as the posterior black shale. Outcrops of what seems to be the same bed have been opened at four different places, the distance between the extreme points being about fifty miles, including twelve or more faults. Its position is everywhere two or three hundred feet above the main trap sheet.

A more precise statement of the location of the fossiliferous strata and a provisional list of the fossils found in them is presented by Mr. Loper.

On examining the tables of species as made out by Mr. Loper, there appears to be good reason for concluding that different outcrops of the two beds of shale might be distinguished as belonging to two horizons on paleontological grounds alone; but it should be borne in mind that there is still much possibility of finding various species, now known only from one of the beds, in the other. The large number of species from the old Durham locality means in part good conditions for their preservation, but it means also that this locality has been more carefully worked and for a longer time than any other. It may also be suggested that while the stratigraphic correspondence of the several outcrops of the anterior and posterior shales was very satisfactory, so far as determination by rough pacing measures would determine, it is quite possible that they do not represent precisely equivalent horizons, although they are certainly as nearly equivalent as the so-called geological horizons commonly are. It is not unlikely that there may be several fossiliferous layers at slightly different horizons of the anterior and posterior shales, and that our openings touch one of them at one point and a second at another. Indeed, it may be that there are various fossiliferous black shales scattered through the formation, yet not visible owing to their weakness and the heavy drift cover that so effectively blankets over the surface; but the main question of the repetition of certain fossiliferous beds at definite positions in the various faulted blocks seems to be settled. The occurrence of the two shales at predicted localities and the correspondence in the fossils of each horizon at various localities so fully conform to the requirements of the theory of the faulted monocline that this structure may now be regarded as established for Connecticut on paleontological as well as on structural evidence.

HARVARD COLLEGE, CAMBRIDGE, MASS., *December*, 1890.

The most marked features of this comparison are the absence of *Ischypterus gigas* from the anterior shales, where so many other species of fish are found, and the limitation of several species of plants to the anterior shales, although the flora of the posterior shales embraces a number of species common to both.

RESULTS.

The work has, therefore, been not only clearly confirmatory of the theory of a faulted monocline, but it has also secured many fine specimens for the National Museum, and it has shown that systematic exploration may yet reveal much of interest where it was supposed that but little remained to be discovered.

WASHINGTON, D. C., *December*, 1890.

DISCUSSION.

Professor C. H. HITCHCOCK: Being greatly interested in the facts of this paper, I desire to ask Professor Davis where, judging from his conclusions as to Connecticut, we should expect to find the fish beds in connection with the Holyoke-Tom range in Massachusetts?

Professor W. M. DAVIS: The location of the belts of shale in Massachusetts will depend on the correlation of the trap ridges of Connecticut and Massachusetts. Without being able at present to settle the question, I am inclined to believe that the anterior sheet in Connecticut thickens northward and becomes the main sheet north of the state line, while the main sheet of Connecticut thins and becomes a subordinate posterior further northward. If this is correct we should look for the anterior shales of Connecticut on the back of the Mount Tom-Holyoke range; and the Bear's Hole locality, a mile or two north of the Westfield river, appears to confirm this suggestion. The posterior shales of Connecticut should lie further east, but they are not yet identified.

Professor B. K. EMERSON: Further northward, in Massachusetts, a band of black shale occupies the same horizon above the Holyoke traps, but has furnished only plant remains. In northern Massachusetts the Sunderland and Turners Falls fish beds also occur just above the Deerfield trap sheet.

The erosion epoch between the Potomac formation and the Cretaceous greensand is one of considerable moment, but the gap between the Potomac and Newark represents one of the great periods of uplift and erosion which is second only to the gap between the Paleozoics and the Newark formation.

SEVERN FORMATION.

Distribution and Characteristics.—In 1888, Clark identified the Cretaceous formation on the "western shore" of Maryland by the discovery of typical molluscan casts at Round bay on the Severn river, on Magothy river, at Millersville and Collington, and at Fort Washington, and so set at rest any question in regard to the southward extension of the formation, at least through Maryland. The writer has found that the formation is a continuous sheet, clearly defined in its stratigraphic relations, and finally disappearing near the latitude of Marshall Hall, on the Potomac river, south of Washington.

The formation consists throughout almost entirely of fine black sand, more or less flecked with scales of mica, very sparingly but irregularly glauconitic, and usually containing considerable carbonaceous materials. The finest exposures are in the high cliffs at Round bay, on the Severn river, a locality to which Clark and Uhler have paid considerable attention. There it is exposed lying on an irregular surface of a local coarse gray sand bed in the Potomac formation; and back from the river, on some of the higher lands, it is in turn capped by weathered beds of the Pamunkey formation, beneath which it also disappears down the river toward Annapolis. Southward there are frequent exposures in road, railroad and stream cuts, in a narrow belt which extends continuously nearly to Washington; thence its edge is cut out for a few miles by an overlap of the Chesapeake formation, but it comes out again opposite Alexandria and is exposed in considerable force in the gullies along the face of the terrace fronting the Potomac and in some of the side drainage ways. At Fort Washington it is exposed in the "bluff," lying on gray lignitic clays of the Potomac formation, and capped by a few feet of weathered Pamunkey deposits.

At every exposure organic remains are found, commonly in the forms of casts or impressions. At several localities east and southeast of Washington and a short distance from the city I have found fossil shells occurring abundantly in the formation, notably *Exogyra costata* and a large *Cyprimeria*, like *densata*.

Northward from Round bay the formation is exposed in the lower Magothy river for the last time on the "western shore." On the eastern side of Chesapeake bay the black carbonaceous sands are again exposed, lying on the Potomac sands and clays at Howell's point, and thence occupying the high banks of the lower Sassafras river, finally sinking beneath the Pamunkey

in Maryland coarser materials gradually increase in amount, and in the Washington-Baltimore region and northward gravel beds predominate. On Good Hope hill, east of Washington, the high terrace is capped for some distance by beds consisting mainly of large pebbles and sand, with a buff loam matrix. Farther eastward the proportion of loam increases and the pebbles decrease in size and number. In the high terraces extending westward from Alexandria, in the outliers west of Washington and Baltimore, in the high terraces southeast of Baltimore, and generally along the crystalline border in Maryland and Delaware, the formation consists mainly of iron-stained pebbles in a matrix of more or less sandy orange or buff loam. Thin layers and lenses of ferruginous conglomerates are of frequent occurrence in the northern Maryland belt, in the capping on Elk neck, and in the Pennsylvania and New Jersey outliers. In some cases the formation contains somewhat coarser materials adjacent to the larger drainage depressions, especially on the Potomac river, where the pebble beds are particularly noteworthy.

The thickness of the formation is variable, but it averages between 20 and 30 feet. In Maryland it is generally under 25 feet, but in Virginia it is usually somewhat thicker than this.

Stratigraphic Relations.—The Appomattox formation lies on a terraced surface comprising in various regions all the preceding formations of the coastal plain series. In Virginia and the southern part of the "western shore" of Maryland it lies on the Chesapeake formation over an area of several thousand square miles. It overlaps upon the Pamunkey formation in the Fredericksburg region, northeast of Washington, and in the James, Pamunkey, Mattaponi, Rappahannock and Potomac depressions. In several isolated knobs on Elk neck it lies directly on the Cretaceous greensand series. It lies on the Potomac formation in the Hanover Junction region, about Fredericksburg, in the wide terraces west and south of Alexandria and Washington, in the Baltimore region, and thence northward in Maryland and probably in Delaware. In the Richmond coal field and about Hanover Junction it lies on the Newark formation, and all along the western edge of the coastal plain region it overlaps for a greater or less distance upon the crystalline rocks in Virginia, Maryland and Delaware.

Generally the base of the formation is sharply demarked, but frequently it is composed of local materials which merge more or less gradually into the surface of the underlying formation. This is particularly the case in some contacts with the lower Chesapeake, Pamunkey and Potomac formations, which have furnished much of the Appomattox materials.

The surface on which the Appomattox formation was deposited is a series of gently rolling plains, separated by gentle slopes and low local terrace scarps. These terraces and slopes descend successively eastward with varying intervals and amounts, and the plains have also a very gentle eastward

the relations of the actual fault line are mostly exhibited. The displacement, as a whole, appears to be continuous throughout, but its amount varies, and in some areas the effects of dislocation become indistinct through diminution in amount, distribution through a zone, or merging into a flexure.

South of Baltimore, near Relay, the relations of the dislocation are particularly well exhibited, and the amount of displacement is fully 250 feet. The relations in this region are shown in section 2, figure 1, page 435. At the exposures in this vicinity, clay caps the bare steep slope of the crystalline fault scarp, and at the base, on the downthrown block, a greater or less thickness of clay abuts against it. This relationship is general for some miles south from Baltimore, and west of the city it is exhibited in diminished amount near Loudon Park cemetery, beyond which evidence of the dislocation is lost for some distance.

Northeastward from Baltimore the effects of the dislocation soon become prominent, and its line is marked by a steep scarp in the crystallines, which extends with varying heights and degrees of distinctness through northern Maryland into Delaware and beyond. Usually the Potomac and Appomattox materials are either eroded back from the summit of the scarp for some distance or entirely removed, and in the larger depressions the drainage has cut through a greater or less thickness of Potomac materials on the downthrown side, exposing the crystalline floor for a mile or two eastward.

At Washington a dislocation traverses the thin outlying feather edges of the Potomac formation and its Appomattox cap just west of Georgetown, and crosses the Potomac river just below the fall line. Thence through northern Virginia the dislocation gives rise to a prominent scarp on each divide, which is more or less continuous and distinct for many miles. At first it dislocates the Appomattox, together with, at some points, a feather edge of the Potomac; but in the region between Occoquan and Fredericksburg its amount increases greatly and it traverses a considerable thickness of the Potomac, at one point the western edge of the Pamunkey, and in most cases the Appomattox, with a throw of from 150 to 300 feet, as shown in sections 3 and 4, figure 1 (page 435).

This dislocation crosses the Rappahannock a mile above Fredericksburg, and its relations are there well exposed. It has not been definitely traced southward, but there is evidence of displacement near Richmond and Petersburg, which may be along a continuation of this same dislocation.

Date.—The date of the displacement is in the main post-Appomattox, but there is some evidence that a series of local movements occurred before the epoch of Appomattox deposition. The greater part of the displacement was effected between Appomattox and Columbia times, apparently just before Columbia deposition. In the gorge of the Potomac river a narrow Columbia terrace extends for some miles above the line of dislocation, and the relative

years ago that the least troublesome hypothesis of the origin of the Great Lake basins was by their excavation by glaciers; but the writer, going into a field of investigation almost sealed by prejudgment, has shown that glaciers did not scoop out the basins, and has otherwise found satisfactory explanation of their origin * without invoking the necessity of ice being converted into rock-diggers. So, also, the evidence of glacial dams has not been found, so far as my investigations have extended.

Let us examine how the glacial-dam theory applies to the shore-lines already described.

The physical features of the Ontario basin are the most favorable for the constructions of a great lake retained by glacial dams. As proved by its deformation, the Iroquois beach was formed at sea-level. If this proof of the altitude of its birth-place did not exist, the evidence of its elevation would be obtained from a consideration of the ability of glaciers to close the St. Lawrence valley to the northeast. Such a barrier would have been from 60 to 100 miles wide and from 800 to 1,300 feet deep (below surface of water), according to location. Yet the drainage of the then expanded lake, over 300 miles long (so far as surveyed) and 100 miles or more in width, was against, into, or under the supposed glaciers, except to a limited extent in its earliest stages, when a partial overflow was by the Mohawk valley. Had the lake been above sea-level, a river as large as the St. Lawrence would soon have eaten its way through the ice and lowered the lake, for in that direction alone it had to flow; consequently, it appears that the great cut terraces and beaches, requiring centuries or millenniums of time, could not have been formed except at sea-level.

If the Algonquin beach of the upper lakes were formed in a glacial lake, then the ice barrier in the region of Lake Nipissing would have reached 600 or 700 feet beneath the surface of the water. The drainage must have been under the ice, and have amounted to a discharge equal to that of the modern Detroit river, as the discharge of Lake Superior, Lake Michigan and Lake Huron basins would have been thus borne seaward, descending 300 feet to the level of the Iroquois water. Under such conditions, the question may be asked, How could the lake surface be retained long enough at any level to carve out the deeply graven water lines and terrace plains of the Algonquin beach, in place of the discharging waters melting away the icy barriers, which were supposed to have been the means of retaining the lake 300 feet above the level of the Iroquois waters?

We now rise to the shores which bounded the Warren water. These I have explored from Lake Michigan to New York, and to northeast of Toronto, upon the Ontario peninsula. Upon the glacial-dam theory, this sheet

* "Origin of the Basins of the Great Lakes of America," by J. W. Spencer: Quart. Journ. Geol. Soc., vol. XLVI, 1890, p. 523.

had scarcely begun, and, consequently, even the modern highlands north of the Great Lakes were then very much lower than now, when compared with the region to the south. I cannot hesitate forming a conclusion that the evidence is in favor of a late continental subsidence rather than in favor of glacial lakes hundreds of miles long and broad, like nothing ever seen, and which could not answer the requirements.

The difficulty in accepting the subsidence without the occurrence of marine shells has in part been pointed out. But their absence in the lower beaches may be accounted for, in part, by the sheets of water being more or less cut-off from the sea and receiving great quantities of fresh water. This, however, will not explain their absence on the higher beaches. The varying climatic conditions of the water and the changes of level destroying the life, too rapid to allow of remigration, may in part account for the absence of organisms in the seashore lines.

The record of subsidence deciphered in the high shore-lines of the lake region is supported by the observations of Dr. G. M. Dawson, Mr. R. G. McConnell and others, on the monuments rising above the great plains of northwestern Canada, and on the mountains between there and the Pacific coast. Dr. Dawson * finds gravel terraces upon the high sides of the Rocky Mountains, facing the east, in position showing their origin not to have been river terraces.

From extensive observations Dr. Dawson concludes that the Pleistocene submergences amounted to 4,000 or 5,000 feet in the region of the international boundary (the 49th parallel), while in Alaska it did not exceed 2,500 or 3,000 feet. He also postulates two episodes of submergence, the latter being less extensive than the former. Further, he regards the elevation and subsidence of the great plains and western mountains as alternating, and that the drift material of the plains was deposited at sea-level.

Mr. R. G. McConnell informs us that on Cypress hills, with an altitude of 4,800 feet, the drift does not rise above 4,400 feet. One hundred and fifty miles northwestward, the drift is not found above 3,400 feet on Hand hills (Tyrrell); but south of Cypress hills, near the 49th parallel, the drift occurs up to 4,660 feet on Three Buttes (Dawson). From these observations Mr. McConnell shows a differential level of 7.2 feet per mile, the elevation being greater nearer the 49th parallel.

In the east, the history of the changes has not been fully deciphered. Erratics occur on top of Mount Washington to 6,300 feet, while on Mount Katahdin, in Maine, they occur only to 4,400 feet (Upham). Conforming with Dr. Dawson's views, as applied to the west, we have a greater rise in the White mountains than eastward. The altitude of beach formation on

* "Later Physiographical Geology of the Rocky Mountain Region in Canada, with Special Reference to Changes in Elevation, and the History of the Glacial Period:" Trans. Roy. Soc. Can., vol. VIII, sec. IV, 1890, pp. 3–74, pls. I–III.

[illegible]

[illegible]

[illegible] geanticlinal movements causing [illegible] producing conditions which have greatly modified the physical features, climatic conditions and distribution of life.

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ON THE GEOLOGY OF QUEBEC AND ENVIRONS.

BY HENRY M. AMI, OF THE GEOLOGICAL SURVEY OF CANADA.

(*Read before the Society December* 31, 1890.)

CONTENTS.

A larger collection of specimens from this locality would be interesting. With the exception of *Leptobolus insignis*, Hall, *Bellerophon bilobatus*, Sowerby and *Triarthrus becki*, Green, all very characteristic Utica species, the forms are not well preserved.

About a mile west of Charlesbourg church, on the road to Lorette, the black bituminous shales of the Utica again crop out in a small brook, and the following forms occur:

Climacograptus, sp. ind.;
Orthograptus quadrimucronatus;
Leptobolus insignis.

L'Abbé Laflamme, of Laval university, who has devoted considerable attention to the geographical distribution of the different terranes in this district for the Canadian geological survey, collected a large slab of somewhat indurated black calcareous and bituminous shale in which were the following species:

Orthograptus quadrimucronatus;
Leptobolus insignis;
Triarthrus becki.

Pointe-aux-Trembles.—In 1888, Dr. Ells obtained the following species of Utica fossils, overlying the Trenton limestones of Pointe-aux-Trembles:

Orthograptus quadrimucronatus;
Leptobolus insignis;
Triarthrus becki.

These three forms are, as can be readily seen, typical and characteristic and generally abound in every collection of Utica specimens.

The Lorraine: General Character and Distribution.—The Lorraine shales form the fourth of the series of geological terranes occurring along the line of section from north to south, and consist for the most part of very thin, fissile and evenly bedded calcareo-argillaceous and arenaceous shales, weathering yellowish brown, measuring a thickness of 800 or 900 feet, and overlying the black bituminous shales of the Utica terrane conformably. They are extensively developed north of the city of Quebec, at Montmorency falls, at St. Nicholas, along the southern shore, and also farther eastward along the northern end of the Island of Orleans. These shales are not very fossiliferous in most of the exposures, but sufficient fossil evidence has been obtained to fix the position of the shales in the region where the thrust fault which occurs has disturbed the strata considerably. They are separated from the Quebec city massif by the thrust fault already indicated (which is evi-

[illegible]

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Montcalm Market.—Immediately south and again about one hundred yards southwest of Montcalm Market, in the city of Quebec, we have a series of dark bituminous and calcareous shales holding abundance of graptolites, brachiopods, ostracods and trilobites, with bands of thinly bedded limestones and an occasional hard, compact, quartz-bearing band which resembles a conglomerate. The strike of the strata here is N. 45° E. magnetic, and the dip about 70°, increasing to 78° in some instances. From the exposures north of St. Patrick street and between the roads leading from that street to the market the following fossils have been obtained:

Diplograptus foliaceus;	Crinoidal fragments;
" *angustifolius*;	*Lingula*, sp. nov. (no. 1);
" sp. und.;	" " (no. 2);
" *euglyphus*;	" " (no. 3);
" *mucronatus*;	*Paterula* (?), sp. nov.
" *whitfieldi*;	*Discina*, sp. nov. (no. 1);
Climacograptus scalaris,	" " (no. 2);
" var.;	Gen. nov. et sp. nov.;
" sp. und.;	*Leptæna*, sp. nov.;
" *perexcavatus*;	" allied to *L. sericea*;
" sp. und.;	" allied to *L. quinquecostata*;
" *bicornis*;	*Strophomena* (?), or gen. nov. et sp. nov.;

Distribution of Genera and Species—Continued.

Genera and Species.	Terranes.				
	Lorraine.	Utica.	Trenton.	Quebec.	Lévis.
***BRYOZOA*—Continued.**					
Prasopora lycoperdon, Vanuxem	?				
" *lycoperdon*, Van., var. *selwyni*, var. nov.			x		
Monotrypa incerta, sp. nov.		?			
Diplotrypa quebecensis, sp. nov.				?	
Pachydictya acuta, Hall			x		
Ptilodictya falciformis, Nich.			x		
Girvanella, sp.			?		
Solenopora compacta, Billings			x		
" *compacta*, B., var. *minuta*, var. nov.					
BRACHIOPODA.					
Lingula curta, Hall		x			
" *obtusa*, Hall		x	x		
" *philomela*, Billings			x		
" *riciniformis*, Hall			x		
" *quebecensis*, Billings					x
" *irene*, Billings					x
" sp. und.					x
" sp. nov.					x
" sp. nov. no. 1				x	
" " no. 2				x	
" " no. 3				x	
Obolella, sp.					x
" sp. nov.				x	
Elkania desiderata, Billings					x
Linnarssonia, sp.					x
Leptobolus insignis, Hall		x			
" sp.	x				
" sp. und.					x
Paterula (?), sp. nov.				x	
Schizocrania filosa, Hall		x			
Siphonotreta micula, McCoy					?
Crania, sp.			x		
Discina, sp.	x				
" *pelopea*, Billings			x		
" sp. nov. no. 1				x	
" sp. nov. no. 2				x	
Skenidium, sp.			?		
Strophomena alternata, Conrad			x		
" *deltoidea*, Conrad	?				
" sp. nov.		x		x	
" sp			x		
Leptæna sericea, Sowerby	x			?	
" sp. nov.				x	
" sp. allied to *L. quinquecostata*				x	
Orthis emacerata, Hall	x				
" *testudinaria*, Dalman	x		x		
" sp.	x				

Distribution of Genera and Species—Continued.

Genera and Species.	Terranes. Lorraine.	Utica.	Trenton.	Quebec.	Lévis.
***BRACHIOPODA*—Continued.**					
Orthis pectinella			x		
" sp.		x			
" sp. nov.			x		
" sp. nov.				?	
" sp.					x
Zygospira headi, Billings	x				
Anazyga recurvirostra, Hall	x ?		x		
Stricklandinia (?), sp.				x	
Anastrophia hemiplicata, Hall			x		
" sp.		?			
LAMELLIBRANCHIATA.					
Pterinea trentonensis, Hall			x		
Ambonychia radiata, Hall	x				
" *bellistriata*, Hall			x		
Modiolopsis, sp.	x				
" sp.	x				
Vanuxemia, sp.			x		
Ctenodonta dubia, Billings			x		
Lyrodesma pulchellum, Emmons		x			
" sp.	x				
Orthodesma parallelum, Hall	x				
GLOSSAPHORA.					
Murchisonia gracilis, Hall			x		
" *perangulata*, Hall			x		
Euomphalus, or *Ophileta*, sp. nov.				x	
Bellerophon bilobatus, Sowerby	x	x	x		
Bucania punctifrons, Emmons			x		
Conularia trentonensis, Hall			x		
Theca, sp. nov.			x		
CEPHALOPODA.					
Orthoceras laqueatum (?), Hall			x		
" sp. nov.			x		
Endoceras proteifrome, Hall		x	x		
Lituites undatus, Emmons			x		
OSTRACODA.					
Primitia mundula, Jones				x	
" "			x		
" *logani*				x	
" " var.	?				
" *whiteavesii*, Jones			x		
Aparchites mundulus, Jones			x		
Polycope, sp.				x	
Isochilina amii, Jones			x		

Distribution of Genera and Species—Continued.

Genera and Species.	Terranes.				
	Lorraine.	Utica.	Trenton.	Quebec.	Lévis.
TRILOBITA.					
Shumardia granulosa, Billings	-----	-----	-----	-----	x
Aeglina rediviva (?), Barr.	-----	-----	-----	x	-----
Ampyx, sp.	-----	-----	-----	x	-----
Agnostus, sp.	-----	-----	-----	x	-----
Harpes, sp.	-----	-----	x	-----	-----
Trinucleus concentricus, Eaton	-----	-----	x	-----	-----
" sp. nov.	x	-----	-----	-----	-----
" sp.	-----	-----	-----	?	-----
Bathyurus, sp.	-----	-----	-----	x	-----
Calymene senaria, Conrad	-----	-----	x	-----	-----
Asaphus platycephalus, Stokes	-----	-----	x	-----	-----
" *canadensis*, Chapin	-----	x	-----	-----	-----
" sp.	-----	-----	-----	?	-----
Illænus milleri, Billings	-----	-----	x	-----	-----
" cf. *T. bouchardi*, Barr.	-----	-----	-----	x	-----
Dionide, cf. *D. lapworthi*, R. Etheridge, Jr.	-----	-----	-----	x	-----
Dalmanites callicephalus, Green	-----	-----	x	-----	-----
Ceraurus pleurexanthemus, Green	-----	-----	x	-----	-----
Encrinurus vigilans, Hall	-----	-----	x	-----	-----

Explanation of Plate 20.

Section 1—A sketch section across the strike from Lorette to Lévis in a southeasterly direction (see also Bull. Geol. Soc. Am., vol. 1, p. 464, map accompanying Dr. Ells' paper). It includes the following terranes in their geographical sequence, beginning toward the northwest: *a*. Laurentian or Archean; *b*. Trenton; *c*. Utica; *d*. Lorraine (Hudson River of most geologists); *e*. Quebec (new terrane, separate from others); *f*. Lévis; and *g*. Sillery. The last three, *e*, *f*, and *g*, form part and parcel of the fossiliferous Quebec group, while *b*, *c*, and *d* form the Trenton group, which are separated by a fault—the great Appalachian fault (the "Quebec fault" of Ells, or the St. Lawrence and Champlain fault, or a branch of it, of other geologists).

Section 2—Sketch section at Montmorency falls, across the measures east of the gorge and across the Island of Orleans. The notation is the same as in section 1. The Utica shales are much disturbed here, both in their contact with the Trenton below and with the Lorraine shales above. Below the horizontal Trenton, capping the Laurentian gneiss, there are found calcareous sandstones of Trenton age, which have been called Potsdam "quartzites." A downthrow fault passes in front of the bluff over which the waters fall.

Section 3—Sketch section across the measures near Montcalm market, Quebec city, showing the high angle of dip and the shales with limestones interstratified.

Section 4—A general view of the strata flanking the Citadel hill at the landslide of 1889. The structure there exhibited is that of an inclined denuded anticline.

Section 5—Sketch section through the calcareo-bituminous rocks and compact shales, with conglomeratic cherty bands associated, at Côte d'Abraham, where the monticuliporidæ have been obtained.

Section 6—Sketch section showing the thin, fissile and soft earthy shales of the Lorraine terrane—newer than the Utica—inclined at a considerable angle along the road at Côte Sauvageau, west of Martelle tower no. 4.

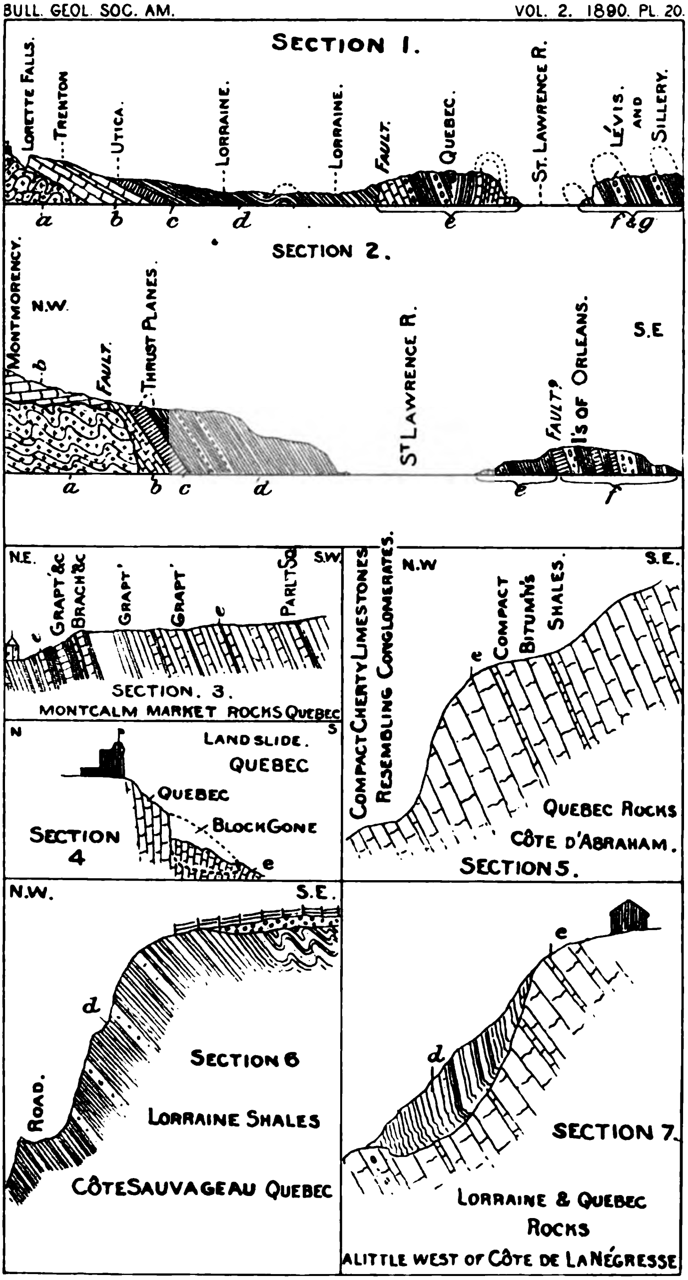
Section 7—Sketch section exhibiting the dying out of the outcrop of Lorraine or newer shales on the edge or brow of the hill near Martelle tower no. 4, between Côte Sauvageau (section 6) and Côte de la Négresse, where a series of impure semi-crystalline, bituminous and fossilifuous limestone occurs. Côte de la Négresse is west of Côte d'Abraham. The contact between the two series is very much broken up, *i. e.*, between *d* and *e*.

Legend.

a = Laurentian or Archean;

$\left.\begin{array}{l} b = \text{Trenton terrane} \\ c = \text{Utica terrane} \\ d = \text{Lorraine terrane} \end{array}\right\}$ Trenton group.

$\left.\begin{array}{l} e = \text{Quebec terrane} \\ f = \text{Lévis terrane} \\ g = \text{Sillery terrane} \end{array}\right\}$ Quebec group.



SKETCH SECTIONS IN THE VICINITY OF QUEBEC CITY, CANADA.

DISCUSSION.

Dr. Alfred R. C. Selwyn:* Sir William Logan alone assigned the rocks of the city of Quebec to the Lévis division of his Quebec group;† Selwyn alone assigned the rocks of the city of Quebec to the Hudson-Utica horizon, or above the Trenton, and pronounced them, before any fossils had been found in them, to be the same as those on the northern shore of the Island of Orleans, which had been assigned by Logan to Hudson-Utica. Fossils since found in the city of Quebec have proved the correctness, so far, of Selwyn's view. Whether Logan and Selwyn are right in placing these rocks above the Trenton is thus the only question now at issue.

Do the fossils determined by Mr. Ami conclusively prove his contention, that they are not above but below? In this connection, see "Geology of Canada," 1863, pages 199 to 204, for list of fossils and description.

Mr. C. D. Walcott: Sir William Logan, in his original definition of the Quebec group, divided it into two parts in the vicinity of Quebec. The Point Lévis series consists of the graptolite-bearing shales of Point Lévis, with their enclosed conglomerates, in which upper Cambrian or Potsdam fossils were found, as he supposed, in association with fossils of the age of the Calciferous formation of New York. Although no fossils were found in the rocks of Quebec city proper they were correlated with the Lévis series. Mr. Ami has now found a fauna in the Quebec city rocks which is distinct from that of Point Lévis, and I think that there should be two names, one for the rocks of Calciferous age at Point Lévis, and another for the Quebec rocks. I think the name Quebec should be restricted to the Quebec city rocks, which carry a distinct fauna from the strata at Point Lévis, and that the name Lévis should be applied to the graptolitic shales and the limestones in which the Calciferous fauna occurs. If Mr. Ami's determination of the fauna is correct, the horizon of the Quebec city rocks is that of the Trenton, probably the lower Trenton, and perhaps the upper portion of the Chazy of the New York section. As the rocks at Quebec are of a peculiar physical development and contain a peculiar fauna, I would suggest, if acceptable to the Canadian geologists, that the name Quebec be restricted to that series of rocks, and that the Point Lévis rocks be arranged under the name Lévis.

For the series of strata that have been formerly included under Quebec as about the Calciferous-Chazy horizon, as originally defined by Logan, which includes the Point Lévis series, the Quebec city series, the Phillipsburg

* In a note communicated to the Society.
† "Geology of Canada," 1863, p. 201.

attempting a minute correlation of its numerous horizons with any beds of the eastern hemisphere, it has been conceded generally that at least the upper portions of this series are of lower Cretaceous age because of their clearly defined stratigraphic position unconformably beneath the Dakota sands, which all authorities have conceded to be of Cenomanian affinities; a conclusion strengthened by the striking paleontologic resemblance of the whole upper Cretaceous (or Meek and Hayden Cretaceous) series to that of Europe. The lower beds of the Comanche series have affinities which entitle them to comparison with the upper Jurassic, while the upper beds have Neocomian and Cenomanian resemblances. The Comanche series as a whole, however, presents great paleontologic evidence at variance with every European standard, and it is premature to make paleontologic correlations with it. In this paper I shall endeavor to clearly define this series stratigraphically, and leave for others the discussion of the faunal resemblances and differences.

The main area of the Comanche series extends from western Arkansas through southern Indian territory to the meridian of 97° 30′, thence southward and southwestward across Texas to New Mexico, a distance of more than 1,000 miles, and then southward indefinitely into Mexico. Areas also exist in the California-Utah province and in eastern New Mexico, although they are as yet unstudied. The main typical area, however, is in central Texas, and is so extensive that deductions as to its subdivisions have required much time; and although I have been constantly studying it for many years, not until now have I felt justified in dividing it into well-defined terranes. I now propose to show by stratigraphic and paleontologic proof that the Comanche series is divisible into several separate and distinct terranes, the lower two of which may possibly be of pre-Cretaceous age.

Definition of the Terranes.

CONSTITUTION OF THE COMANCHE SERIES.

C. The Washita, or Indian Territory Division.
- 11. The Denison Beds.
- 10. The Fort Worth Limestone.
- 9. The Duck Creek Chalk.
- 8. The Kiamitia Clays or *Schloenbachia* Beds.

B. The Fredericksburg or Comanche Peak Division.
- 7. The Goodland Limestone.
- 6. The *Caprina* Limestone.
- 5. The Comanche Peak Chalk.
- 4. The *Gryphæa* Rock and Walnut Clays.
- 3. The Paluxy Sands.

A. The Trinity Division.
- 2. The Glen Rose or alternating beds.
- 1. The Trinity or Basal Sands.

The Paluxy Sands.—North of the Colorado-Brazos divide the alternating beds of the Trinity division are succeeded by a terrane of fine, white pack-sand, oxidizing red at the surface, about 100 feet in thickness, resembling very much the Trinity sands and hitherto confused with them. They outcrop along the eastern edge of the Brazos valley, in Parker and Hood, and also in Erath, Comanche, Coryell and Bosque counties. South of the Colorado-Brazos divide they disappear, the Comanche Peak beds resting directly upon the Glen Rose beds. These beds are especially conspicuous southwest of Granbury, forming the timbered upland of that region.

The Paluxy sands, which are so called from the town and creek of that name in Somerville county, can first be separated from the Trinity sands in Wise county at a point between Decatur and Alvord. At Decatur the beds are well developed. In general character they are somewhat similar to the Trinity sands. There are differences, however: the Paluxy sands have none of the fine pebbles which characterize the base of the Trinity; and the Paluxy beds are rather calcareous and argillaceous in places, while those of the Trinity are more ferruginous.

At Decatur the Paluxy sands contain some layers of honey-combed and very argillaceous limestone. The gradation from the Paluxy to the overlying and underlying beds at Decatur is also rather gradual. At Comanche peak the sands form the plain upon which the butte stands, making a belt of forest region surrounding its base. Here the beds have a thickness of about a hundred feet, and are of character similar to that at Decatur. West and south of Comanche peak they occupy a considerable area, while they extend many miles down the Brazos, finally disappearing at the Bluff mills, near Kimball, where they make the shoals over which the river runs. Jonesborough, Coryell county, is situated directly on the outcrop of these sands, and the Lanham road northward from the town crosses it several times. A few miles north of Jonesborough the sands have a thickness of only about fifteen feet, showing their decreasing thickness southward. The transition from the sands to the underlying Glen Rose alternating beds is rather sharp, but that of the overlying beds is a little more gradual, for which reason these sands are placed in the Comanche division.

The sand is stratified, and occasionally cross-bedded, and there are local hardenings. The color varies from gray to yellowish, and the amount of ferrugination which is here found is variable. The sand is also marked by the growth of forest timber, largely post-oak, though smaller growths, such as sumac, also occur. The sands probably extend for a considerable distance down the Leon valley, although it is difficult to determine their exact extent on account of confusion with the drift of the Leon river, composed of this débris. The sands appear only in scattered spots further toward the south. Thus, east of Burnet, on the Mahomet road, they appear as

subdivisions, because I am not yet in possession of any very clear ideas upon that subject. It is only intended to show graphically the effect of the assumed correlation to which I have referred; that is, if we draw a line from the space representing the Dakota to that representing the Cenomanian, and another line from the space representing the Comanche to the upper part of the one representing the Turonian, they will cross each other. The shifting of the relative position upward or downward of the right-hand and left-hand portions of this table to meet the views of different persons as to the general correlation of the American and European Cretaceous will not affect the fact intended to be expressed by the crossing of the lines between them.

Montana group.	Danian.
Colorado group.	Senonian.
Dakota group.	Turonian.
(*Hiatus.*)	Cenomanian.
Comanche Series.	Gault.
	Neocomian.

Many similar cases of theoretical paleontology at fault might be cited, to some of which I have already called attention in my writings, but which I have not now time to consider. I think I am justified in saying that theoretical attempts like these at special correlation of subdivisions of any geological system for different continents are unscientific, and, with due respect to those who hold different views, that it is time we were done with them.

Professor HILL: All analogies between the American and European formations seem to cease when we reach the Comanche group; yet there are many species of the Comanche which are almost indistinguishable from European forms, and afford the paleontologists of the old world a foundation for their attempted correlations.

Mr. C. D. WALCOTT: Professor Hill has brought up the question debated by many geologists—whether the Cretaceous and later formations ever extended over the central Paleozoic area of Texas. A few years since I examined the latter rocks of this area and saw the escarpments of the Cretaceous strata facing the central Paleozoic area. As the last report of the

A PROPOSED SYSTEM OF CHRONOLOGIC CARTOGRAPHY ON A PHYSIOGRAPHIC BASIS.

BY T. C. CHAMBERLIN.

Read by title before the Society December [illegible], in connection with the memoir by Professor [illegible] on the Origin of certain Topographic Forms.

The determination of time-relations has been based chiefly upon aqueous deposits. Attention is now turning more than heretofore to the study of topographic forms as time indices and as means of correlation. The doctrine of baselevels opened the way to specific studies of land sculpture as a means of determining successively the varying attitudes of the land and their accompanying time-relations. A considerable body of discriminating geologists have become enthusiastic workers in this new field, and are bringing forth results of great interest and value. It becomes evident, upon consideration, that if it is possible to correlate fragments of topography distributed over the face of the continent, we may connect formations at great distances by a physiographic chain, where sedimentary connection is entirely wanting. Many unsolved problems in correlation will yield to the application of the new method, and many tentative correlations will be overthrown by it.

The method has been applied in certain districts sufficiently widely and successfully to render it desirable to devise some satisfactory method of cartographic representation. To illustrate, Professor W. M. Davis, has determined, as he believes, that the remarkably horizontal crest-lines of the Appalachian ranges in Pennsylvania and New Jersey are remnants of a base plain formed in Cretaceous times. He has also determined that a later plain of much wider extent represents a base plain formed in Tertiary times.

will acquire features characteristic of the newer cycle, while the harder members retain features from one or more previous cycles. This corollary is the guiding principle in practical work.

A natural consequence of the continued attack of the destructive forces of geographic development is that the more ancient forms are consumed and obliterated in the production of the new ones. It is therefore characteristic of this kind of work that, as more and more modern time is approached, the recognition of finer and finer subdivisions of time becomes possible. The older cycles that I have identified give us little record now beyond the general statement of a long still-stand. All the presumable minor oscillations during such a period are lost to our belated sight.

All old land forms would be rubbed out were it not for their occasional preservation by burial for a long period, followed by a resurrection, when they may become once more visible. Such surfaces might be referred to two dates: one the date of their first development and burial, the other the date of their rediscovery.

It appears that, when thus regarded, the forms of the land around us have been produced at different times. It is therefore possible to date them in accordance with the geological ages or divisions of time in which they were given their existing forms. In this geological sense, their "age" has an entirely different meaning from the geographic sense in which it has been used above. I shall therefore use the word "date" in speaking of geological time, and reserve "age" for the geographic meaning already indicated.

The Topographic Forms of the Atlantic Slope.

Outline of this Essay.—The thesis maintained in this essay is, in brief, as follows: The Permian and Jurassic constructional topography of the Atlantic slope was practically obliterated over the greater part of the area by the long-continued denudation of Jurassic and Cretaceous times, as a result of which the region was reduced to a lowland of faint relief—a peneplain. The only considerable elevations that remained above this lowland were in the White mountains of New Hampshire and the Black mountains of North Carolina, with their extension in the Blue ridge of Virginia. This Cretaceous lowland was uplifted about the opening of Tertiary time, and constitutes the upland surface of our highlands. The valleys and open lowlands of to-day have been etched during Tertiary time in the uplifted Cretaceous peneplain, their depth depending on the height to which their streams were raised, and their width depending on the weakness of the rocks in which they are sunk. About the close of Tertiary time a moderate elevation occurred, allowing the rivers and streams to trench the lowlands produced in the Tertiary cycle. Near the sea-coast, where changes of level soon have effects of

away toward the west. Looking from its edge eastward, the trap-ridges of the Connecticut valley are seen rising to about the same height as the plateau, and beyond them portions of the corresponding eastern crystalline plateau may be seen, still closely accordant with the same general scale of elevation. The valleys and lowlands by which the plateau is interrupted may be filled again in imagination to the general level of its surface, and we shall have then restored a part of one of the more important elements, if not the most important element, in the topography of the Atlantic slope. The restored surface is not by any means perfectly even; but its inequalities are moderate, and it may be justly called a peneplain. It is manifestly a surface of denudation, for it is not at all in sympathy with the disordered structure of the crystallines or with the faulted monocline of the Triassic area. It is manifestly a surface of long-enduring denudation at about the same altitude of the land, for otherwise it could not have been reduced to so nearly level a surface as its parts now show its whole to have been before the present valleys were sunk into it. It is manifestly a product of denudation, not at the present altitude of the land, but when the whole region stood at a less altitude, such as would place the surface of the old peneplain close to base-level.* The form, extension, and date of completion of the peneplain, the date of its elevation to its present altitude, the tilting it may have suffered in elevation, and the time during which the valleys that now break it have been excavated, are to be examined.

The form of the peneplain may be seen from any one of the many slightly higher points of its upland surface. For example, taking the Air Line railroad eastward from Middletown, Connecticut † (see figure 1), one soon passes from the open Triassic lowland to the narrower valleys that are cut in the harder crystalline rocks of the eastern plateau; and at the little station of Cobalt, a road toward the north leads to Cobalt hill. The hill consists of a hard quartzitic schist, and affords a fine prospect over the surrounding country toward the east, south, and west. The prevailing feature of the view is the general evenness of the uplands. There are no summits rising like mountain peaks above the general level. The valleys that are cut below it will be referred to in a later paragraph. If an excursion be made eastward from Springfield, Massachusetts, to the hills of the plateau back of Wilbraham, the evenness of the upland is less marked; a number

* See the Topographic Development of the Triassic Formation of the Connecticut Valley, by W. M. Davis: Amer. Journ. Science, 3d ser., vol xxxvii, 1889, pp. 423–434.

† The various towns, rivers, and geographic districts mentioned in this paper are indicated by initial letters on several rough diagrams. The last pages of the essay contain an index of names and abbrevations employed. The diagrams have been prepared in the hope that they might serve a useful purpose to those readers who are not familiar with the details of the region under consideration, for my own experience in reading has shown me that geological arguments of relative simplicity are often obscured by the geographical integument that encloses them. The atlases in common use generally fail to locate small towns and streams; special maps of state surveys are often difficult to examine, as they present much more than is wanted. A good map, especially prepared for this paper, would be too expensive. Diagrams are therefore attempted, somewhat experimentally.

The uplifted Cretaceous Peneplain in the New Jersey Highlands.—**The New Jersey highlands are in many ways homologous with the Berkshire highlands of Massachusetts. They are both composed in greatest part of crystalline rocks; both are greatly disturbed; both lie between belts of Triassic deposits on the east and Cambrian strata on the west. The correspondence may be found in form as well as in structure and associations. The highlands of New Jersey possess in a conspicuous degree the evenness of summit outline that prevails in Massachusetts. Standing on the northern end of Schooley's mountain, near the center of the highlands (see figure 2), the surrounding members of the plateau show a marked tendency to rise to the**

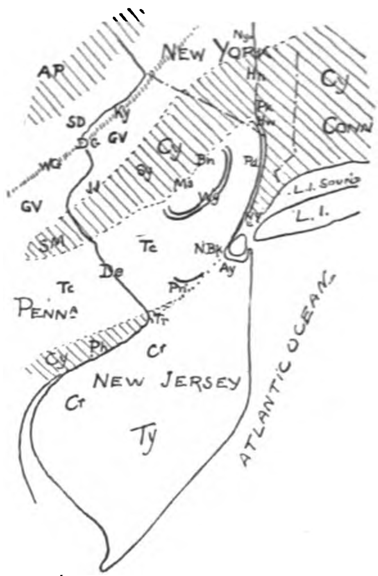


FIGURE 2—*Cretaceous Peneplain in New Jersey.*

general upland level, but not to pass above it. This feature was recognized by Professor Cook some years ago, although it does not clearly appear that he explained it as a result of denudation while the region stood at a less altitude. He wrote:

"The Highland mountain range consists of many ridges, which are in part separated by deep valleys and in part coalesce, forming plateaus or table-lands of small extent. Some of the included valleys are quite as deep as the red sandstone plain on the south and the Kittatinny valley on the north and west. * * * A characteristic feature is the absence of what might be called Alpine structure or scenery. There are no prominent peaks or cones. The ridges are even-topped for long distances and the average elevation is uniform over wide areas. Looking at the crests alone, and imagining the valleys and depressions filled, the surface would approximate to a

[illegible]

[illegible]

[illegible]

	Feet.
20—Cross-bedded gray sands and clay	15
21—Sandy stratum, indurated and containing *Ostrea* sp.*	1
22—Gray highly fossiliferous marl. The fossils are nearly, if not quite, all bivalves and are mostly comminuted as if they formed an ancient shore-line. There are numerous shark and sauroid teeth, mammalian bones, a hard bony substance in sections resembling the under shell of a turtle, black coprolitic pebbles, and fragments of lignite	3
23—Gray and yellow sands resembling physically those of the Tertiary at Lower Peach Tree, Alabama*	30
24—Gray sand intermingled with thin seams of more argillaceous sand, all of which is unfossiliferous	26
25—Gray sandy calcareous clay, with lines of bowlder-like concretions projecting from the bank; first seen at Lawson's wood-yard, Georgia. Few fossils except *E. costata*, Say, occur in the lower part of this stratum. A mile above Blufftown, Georgia, characteristic Ripley shells, mainly bivalves, are found in a much decomposed state throughout a stratum 6 to 8 feet thick, while the uppermost 10 feet of the entire stratum is very fossiliferous. Near Jernigan's Landing, Alabama, slight rolls in the strata are seen, involving about 20 feet of the sands. These miniature anticlinals and synclinals continue to within two miles of Florence, Georgia	120

Eutaw group.

Tertiary Strata.

Thickness and Divisions.—Hilgard † appears to be somewhat in doubt as to the exact thickness and characteristics of the Tertiary in Mississippi, placing it at about 620 feet, exclusive of the Grand Gulf, which is probably post-Eocene.

Smith ‡ divides the Eocene into three parts: the lower, consisting of the Midway, Black Bluff, Matthews' Landing or Naheola, Nanafalia, Bell's Landing or Tuscahoma, Wood's Bluff or Bashi, and Hatchetigbee; the middle, comprising the Buhrstone and Claiborne; and the upper, which includes the Jackson and Vicksburg; in aggregate thickness reaching about 1,700 feet. In the Chattahoochee water-shed the total thickness is not more than 1,200 feet, and many groups represented along the western border of the state are entirely lacking, while others are so attenuated as to have almost lost their identity.

The Midway or Clayton.—At the typical locality on the Alabama river, the Midway group consists of 10 feet of light gray, very argillaceous limestone, characterized by *Nautilus (Enclimatoceras) ulrichi*, Hyatt. Following the group eastward for 20 miles to the vicinity of Allenton, Alabama, this limestone has lost its argillaceous character, and is underlain by an additional 15

* Ibid., p. 46.
† Agric. and Geol. of Miss., 1860, pp. 107–110.
‡ Bul. 43 U. S. Geol. Survey, 1886, p. 16.

ical outcrop on the Alabama river. No stratum that could be referred to this horizon has been noted east of Monroe county, Alabama, or more than twenty miles from Claiborne.

Beneath the Claiborne sands lies a bed of gray calcareous sand characterized by numerous shells of *Ostrea sellæformis*. Contrary to the opinion of A. Winchell,* this has proved to be the most persistent member of this group, having been traced by the writer personally from Suanlovey creek, near Garlandsville, Newton county, Mississippi, to the Georgia line. In general characters it does not vary throughout its extent, being about 75 feet thick on each of the three rivers.

The lowest division of this group appears to be confined to the region drained by the Alabama and Conecuh rivers. It is about 45 feet thick, and differs from the preceding mainly in a peculiar group of fossils that have as yet been but imperfectly studied.

The total thickness of this group, as given in Smith's general section,† is 145 feet, as compared with 75 on the Chattahoochee, where the *Ostrea sellæformis* bed is the sole representative.

The White Limestone.—The youngest member of the Eocene in the Gulf embayment was considered Cretaceous until Lyell's second visit to this country, Morton ‡ having described the characteristic fossils and referred them to the Cretaceous. To facilitate comparison, the group may be subdivided into the Jackson and Vicksburg.

Hilgard § mentions the occurrence of lignitic clay between the Jackson and Vicksburg groups. Attention has already been called ‖ to beds of lignitic sand intercalated between the calcareous Jackson clays exposed on Pearl river, Mississippi. At Red Bluff, Mississippi, near the Alabama line, the upper part of the lignitic clays contains an abundance of marine forms, while at the Alabama line these clays have become so calcareous and barren of fossils that they blend imperceptibly into the prairie-making rocks of the Jackson.

The Jackson sub-group, consisting of gray and white calcareous clays in a general way devoid of fossils except a few *Zeuglodon* vertebræ, has been traced from the Yazoo river to the Sepulgah, east of which it becomes more sandy and ferruginous until, on reaching the Chattahoochee, it is almost a counterpart of Smith's *Scutella* bed.

The Vicksburg, or orbitoidal limestone is, at its typical locality, rather a calcareous sand than a limestone, changing on Pearl river into occasional ledges of indurated subcrystalline limestone, and from the Mississippi–Alabama line to the Chattahoochee it assumes a white chalky phase which constitutes practically the entire group. The total thickness of the group is, in

* Proc. Am. Assoc. Adv. Sci., vol. X, part II, 1856, p. 86.
† Op. cit., p. 18.
‡ "Synopsis," 1833.
§ Agric. and Geol. Miss., 1860, pp. 107–110.
‖ Author, Am. Journ. Sci., 3d ser., 1886, vol. XXXI.

	Feet.
22—Gray fossiliferous marl, shells much decomposed. An occasional lignitized log and numerous slightly phosphatic nodular masses containing fossils occur in this stratum	5
23—About the same in general character as 21, but contains indurated ledges about a foot thick, which show the dip to average 40 feet to the mile, with numerous rolls; ends just above the mouth of Cowikee creek, Alabama	170
24—Soft, less coherent sand, gray in color; appears at the mouth of Cowikee creek, Alabama, from which the southern bank of the creek, composed of this stratum, may be seen to rise 50 feet from the water	60
25—Gray calcareous sand, with indurated ledges, containing *Exogyra costata*, Say; *Gryphœa mutabilis*, Mort.; *Hamulus onyx*, *Plicatula urticosa*, *Anomia*, sp.; forms the shoal at Frances bar and bluff at Eufaula, Alabama	190
26—Light-gray and yellow sands, interlaminated with sand darker in color, more argillaceous, and containing bits of lignitized leaves and twigs; no other fossils seen; crops out in the gullies of Eufaula next below the Orange sand	20
27—Massive gray sand, with a few fragile fossils and bowlders. This sand is only slightly calcareous, and is more or less lignitic; dip here about 100 feet to the mile	40
28—A more calcareous sand, filled with *Exogyra costata*, Say, and many indurated ledges, giving rise to the first bar below Eufaula	70
29—Light-yellow cross-bedded sands enclosed between indurated ledges	20
30—Calcareous gray sands, with bowlders	50
31—Yellow sands and indurated ledges filled with casts, *Exogyra costata*, Say, and echinoids set fast in the ledges. The sands are cross-bedded and contain some lignitic streaks	35
32—Gray fossiliferous sand, with bowlders. The sand is massive, and is fossil-bearing only in the lowest 5 feet	40
33—Brown laminated argillaceous sand; disappears at the mouth of Pataula creek, Georgia	5
34—Light-yellow sand, interstratified very irregularly with a gray micaceous sand filled with friable Ripley fossils; mouth of Pataula creek, Georgia	30
35—Hard sandy ledge; weathered surface jagged; contains *Exogyra costata*, Say, and echinoids; very light yellow in color, white when dry and not weathered	30
36—Gray sand, with indurated ledges; no fossils seen; merges gradually in the upper part into a dark, almost black, sand containing large nodular masses and interstratified with light-yellow sands	35
37—White coarse conglomerate, the matrix material being calcareous. The quartzose pebbles decrease in size toward the top, and the stratum becomes more argillaceous. There are many casts, but all too obscure for identification	18
38—Massive blue clay; contains a few bits of teredo-eaten lignite (probably top of Cretaceous)	6
39—Massive sandstone; coarse-grained and almost a conglomerate	8
40—Light-yellow silicious limestone, containing a large *Ostrœa* and numerous obscure casts; five miles above Fort Gaines, Georgia	10

Comparative Sections of eastern and western Alabama.

The following tables show the relative thickness of the Tertiary and Cretaceous strata as exposed along the Tombigbee and Chattachoochee rivers respectively:

Formations.

			General* section.	Chattahoochee section.
			Feet.	*Feet.*
Miocene		Alum Bluff	(Not seen)	65
		Chattahoochee	(Not seen)	250
Eocene	*Upper* (White Limestone.)	Salt Mountain	150	(Not seen)
		Vicksburg	140	250
		Jackson	60	25–30
	Middle	Claiborne	140–145	70–75
		Buhrstone	300	170–175
	Lower (Lignitic.)	Hatchetigbee	175	10
		Bashi	80–85	44
		Tuscahoma	140	173
		Nanafalia	200	175
		Naheola	130–150	(Wanting)
		Black Bluff	100	
		Midway	25	218
Cretaceous		Ripley	250–275	1031
		Rotten Limestone	1000	(Wanting)
		Eutaw	300	345
Cretaceous (?)		Tuscaloosa (or Potomac)	1000 (?)	65

* Bull. 43 U. S. Geol. Survey, 1886, p. 18.

Series.

	General section.	Chattahoochee section.
	Feet.	*Feet.*
Miocene	(Not seen)	315
Eocene	1,655±	1,145±
Cretaceous	2,560±	1,441
Total	4,215±	2,900±

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
VOL. 2, PP. 607-662 AUGUST 7, 1891

PROCEEDINGS OF THE THIRD ANNUAL MEETING, HELD AT WASHINGTON DECEMBER 29, 30 AND 31, 1890.

J. J. STEVENSON, *Secretary*.

CONTENTS.

SESSION OF MONDAY, DECEMBER 29.

The Society met in Columbian University at 2 o'clock p. m., Vice-President Alexander Winchell in the chair.

When the meeting was called to order, Mr. G. K. Gilbert, chairman of the Local Committee of Arrangements, introduced President J. C. Welling,

As the sessions of the International Geological Congress begin in Washington on August 26, 1891, it will be well for the Society to hold sessions on the two days prior to that date. This is in strict conformity to the requirements of the constitution, as the American Association for the Advancement of Science will begin its meeting in Washington on August 19, 1891. The Council therefore recommends that when the Society adjourns, it adjourn to meet in Washington on August 24, 1891, at 10 a. m., and that the sessions continue during August 24 and 25.

By formal vote of the Society, the recommendations of the report were adopted.

ELECTION OF OFFICERS AND FELLOWS.

The Secretary announced the result of balloting for officers for 1891 as follows:

President:

ALEXANDER WINCHELL, Ann Arbor, Mich.

Vice-Presidents:

G. K. GILBERT, Washington, D. C.

T. C. CHAMBERLIN, Madison, Wis.

Secretary:

H. L. FAIRCHILD, Rochester, New York.

Treasurer:

HENRY S. WILLIAMS, Ithaca, New York.

Members-at-large of the Council:

Class of 1893:

GEORGE M. DAWSON, Ottawa, Canada.

JOHN C. BRANNER, Little Rock, Arkansas.

Class of 1892:

E. W. CLAYPOLE, Akron, Ohio.

CHAS. H. HITCHCOCK, Hanover, N. H.

Class of 1891:

I. C. WHITE, Morgantown, W. Va.

JOHN J. STEVENSON, New York City.

Editor:

W J MCGEE, Washington, D. C.

The result of balloting for Fellows was announced by the Secretary as follows:

T. NELSON DALE, Newport, R. I. Assistant Geologist on the U. S. Geological Survey; now engaged on structural geology.

ORVILLE A. DERBY, M. S., present address Rio Janeiro, Brazil. Director of the Geographical and Geological Survey of the province of Sao Paulo, Brazil.

ULY. S. GRANT, B. S., Minneapolis, Minn. Now post-graduate student at Johns Hopkins University, engaged in study of crystalline rocks.

EDMUND JÜSSEN, Ph. D., Washington, D. C. Assistant Geologist on the U. S. Geological Survey and engaged on surface and crystalline geology.

WILL H. SHERZER, M. S., Saginaw, Mich. Teacher, and engaged in paleontological work.

The death of Richard Owen was announced by the Secretary, and authority was given to publish the following—

OBITUARY NOTICE.

Dr. Richard Owen, youngest brother of David Dale Owen and Robert Dale Owen, died at New Harmony, Indiana, on March 24, 1890, at the advanced age of somewhat more than eighty years. He was a native of Lanarkshire, Scotland. His education and training, prior to his settlement at New Harmony, Indiana, was partly at Lanark and at Hofwyl, Switzerland, and later at Glasgow, where he had a course of study with Dr. Andrew Ure. He was known as author, teacher, geologist, and soldier. His first geological work was done in association with his brother, David Dale Owen, on the United States survey of Wisconsin, Iowa, and Minnesota, where he was employed mainly on the northern shore of Lake Superior. He published in 1857 a work entitled "Key to the Geology of the Globe," and in 1862 his report on a "Geological Reconnoissance of Indiana." His later scientific publications relate to physical geography and seismism, and are principally published in the Proceedings of the American Association for the Advancement of Science and in the American Meteorological Journal. His two sons, Eugene and Horace, now reside at New Harmony.*

On motion of Mr. G. K. Gilbert, the thanks of the Society were unanimously voted to Professor J. J. Stevenson for his services as Secretary and for his efficient labors in organizing the Society.

Mr. G. K. Gilbert made some remarks in announcement of the illness of the President of the Society, Professor J. D. Dana, and Vice-President J. S. Newberry, and moved that the Secretary be instructed to communicate to President Dana and Vice-President Newberry the assurance of the sympathy of the Society in their illness, and hopes for their speedy recovery. The motion was unanimously voted.

* A sketch of the life and work of Dr. Owen, with a portrait, was published in the American Geologist, vol. VI, 1890, pp. 135-145.

The last paper of the afternoon session was—

POST-PLIOCENE SUBSIDENCE VERSUS GLACIAL DAMS.

BY J. W. SPENCER.

This was discussed by G. K. Gilbert. It is printed as pages 465–476, with plate 19, of this volume.

The Society adjourned, to meet at 8 o'clock p. m., in the same place.

Evening Session, Monday, December 29.

The Society convened at 8 p. m., President Winchell in the chair.

The first paper of the evening was entitled:

ILLUSTRATIONS OF THE STRUCTURE OF GLACIAL SAND-PLAINS.

BY W. M. DAVIS AND H. L. RICH.

Professor Davis described the form and structure of glacial sand-plains, and illustrated his remarks by a series of lantern views made from photographs taken by Mr. H. L. Rich, of Auburndale, Massachusetts, who has been associated with him in the study of these deposits during the past year. The text of Mr. Davis' remarks is given in his paper on this subject, read by title only at the New York meeting and published in the Bulletin volume 1, pages 195–202, plate 3.

The second paper of the evening was—

GLACIERS OF THE ST. ELIAS REGION, ALASKA.

BY. I. C. RUSSELL.

The glaciers of the St. Elias range and of the foothills and lowlands between the range and the Pacific ocean were described and illustrated. The glaciers were classified as (1) Alpine glaciers, or ice-rivers of the usual type; and (2) Piedmont glaciers, or broad ice-sheets lying at the bases of mountains and formed by the confluence of Alpine glaciers; and both classes were discriminated from continental glaciers.

The paper was illustrated by lantern views. It is published in full, with other matter, in The National Geographic Magazine, volume III, 1891, pages 53–204, plates 2–20.

The Society adjourned to meet in the same place on Tuesday, December 30, at nine o'clock a. m.

On reässembling, the following paper was read:

THE RELATION OF SECULAR ROCK-DISINTEGRATION TO CERTAIN TRANSITIONAL CRYSTALLINE SCHISTS.

BY RAPHAEL PUMPELLY.

This communication was discussed by Jed. Hotchkiss, G. K. Gilbert, H. S. Williams, B. K. Emerson, F. L. Nason and the author, and will be found, with the more considerable part of the discussion, on pages 209–224 of this volume.

The next two papers were read by title:

A PROPOSED SYSTEM OF CHRONOLOGIC CARTOGRAPHY ON A PHYSIOGRAPHIC BASIS.

BY T. C. CHAMBERLIN.

THE GEOLOGICAL DATES OF ORIGIN OF CERTAIN TOPOGRAPHIC FORMS ON THE ATLANTIC SLOPE OF THE UNITED STATES.

BY W. M. DAVIS.

The papers form pages 541–586 of this volume.

The following communication was then presented:

GRAPHIC FIELD NOTES FOR AREAL GEOLOGY.

BY BAILEY WILLIS.

It was discussed by G. F. Becker, Jed. Hotchkiss, P. H. Mell, and G. M. Dawson. It forms pages 177–188, with plate 6, of this volume.

The next communication was—

MESOZOIC AND CENOZOIC FORMATIONS OF EASTERN VIRGINIA AND MARYLAND.

BY N. H. DARTON.

It is printed as pages 431–450, with plate 16, of this volume.

The next two papers were read and discussed together:

THE CHAZY FORMATION IN THE CHAMPLAIN VALLEY.

BY EZRA BRAINERD.

Printed, with plate 11, as pages 293–300 of this volume.

ON THE LOWER CAMBRIAN AGE OF THE STOCKBRIDGE LIMESTONE AT RUTLAND, VERMONT.

BY J. E. WOLFF.

Printed as pages 331–338 of this volume.

The two papers were discussed by J. F. James, C. D. Walcott, C. H. Hitchcock, and the authors.

The Society then adjourned until 8 o'clock p. m. An auxiliary section, arranged to present papers on the Quaternary, adjourned early in the afternoon.

Following the session of the afternoon the Fellows and ladies partook of an informal dinner, without speeches, at Willard's Hotel.

Evening Session, Tuesday, December 30.

The Society reässembled at 8.10 p. m., and listened to a paper, illustrated with lantern views, entitled—

A CONTRIBUTION TO THE GEOLOGY OF GEORGIA.

BY P. H. MELL.

This was followed by—

ANTIQUITIES FROM UNDER TUOLUMNE TABLE MOUNTAIN IN CALIFORNIA.

BY GEORGE F. BECKER.

Remarks were made on this communication by G. F. Wright, E. D. Cope, H. W. Turner, and the author. The paper, with discussion, will be found as pages 189–200, with plate 7, of this volume.

Mr. J. S. Diller presented the report of the Committee on Photographs, which has been amended and enlarged to read as follows:

FIRST ANNUAL REPORT OF THE COMMITTEE ON PHOTOGRAPHS.

At the meeting of the British Association for the Advancement of Science in 1888, Mr. Osmund W. Jeffs presented a paper on local geologic photography which led, at the next meeting of the Association, in September, 1889, to the appointment of a committee to arrange for the collection, preservation, and systematic registration of photographs of geologic interest in the United Kingdom.

The success of this movement was afterwards brought to the attention of the International Geological Congress in London in 1889. Professor H. S. Williams suggested to Mr. J. F. Kemp the advisability of initiating a similar movement in the Geological Society of America. Mr. Kemp prepared a paper on this subject for the New York meeting of the Geological Society in 1890, but for the want of time it was crowded out. He urged the Secretary to bring the matter before the Council, and at the regular meeting of the Council, held in Washington in April, 1890, the following Fellows were appointed a committee on photographs: Professor J. F. Kemp, Cornell University, Ithaca, N. Y.; Professor W. M. Davis, Harvard University, Cambridge, Mass.; and Mr. J. S. Diller, U. S. Geological Survey, Washington, D. C.

The object of the movement is to make a photo-geologic survey, and secure for the Society a national collection of photographs illustrating the geology of the country. The demands for such a collection, already felt by the committee, are, first, to furnish to teachers better illustrations to use in teaching geology, and, second, to furnish to investigators material for comparative study.

The plan of the committee is: (1) To solicit donations of photographs of geologic phenomena, not only from Fellows of the Geological Society of America, but also from all other persons who can furnish them; (2) To exhibit the collection of photographs thus obtained at the annual meetings of the Society; and (3) To publish annually in the proceedings of the Society a report containing a register of the photographs received during the year.

The committee has issued three circulars. Number 1 was hektographed, and distributed in June, 1890. The same matter was printed and sent out in August, 1890, as circular number 2. The third circular was issued at the Washington meeting of the Society, and has since been distributed from Rochester by the Secretary. It contains a complete, but greatly abridged, list of the donations of photographs received before December 29, 1890.

At that time the committee had received 293 photographs, of which 21 were donated by Professor J. F. Kemp, of Ithaca; 269 by the Geological Survey, through the Director, Major J. W. Powell; and 3 by Professor W. B. Dwight, of Poughkeepsie.

To facilitate exhibition and examination at the annual meeting, and at the same time to ensure preservation, the photographs were classified and temporarily bound together in the form of books, as indicated in circular number 3.

Since December 29, 25 photographs have been received from Dr. George H. Williams, of Baltimore; Professor P. H. Mell, of Auburn, Alabama; and Mr. G. P. Merrill, of Washington, D. C. Professor W. M. Davis announces that he is preparing for the Society a collection of views illustrating the physical features of New England.

The expenses of the committee in printing the circulars and preparing the photographs for exhibition have been about $20.

The committee solicit the donation of good photographs which clearly illustrate important geologic phenomena, among which may be mentioned typical views of eruptive and sedimentary rocks, of dikes, bosses, contacts, transitions, folds, faults, jointing, cleavage, weathering, etc., of glaciers and other geologic agents, as well as of good exposures of definite geological horizons and of characteristic topographic forms, especially those which have a visible bearing upon the geologic history of the country.

Photographs may be sent to any member of the committee. Prints smaller than 4 by 4½ inches are not desired. They should all be mounted; and for artistic effect, as well as ease of preservation, gray cards are preferred.

Each photograph should be plainly labeled, giving the subject, with a brief but explicit reference to what is illustrated by the photograph, its date, locality, and the name of the artist and donor, and a reference to its publication, if the photograph has been published, either in type or plate. The label should be placed, if in type, upon the front, beneath the photograph; if in script, upon the back.

The photographs should be accompanied by a statement whether duplicates and lantern slides can be furnished, and at what price, and the address of the person to whom application for them should be made. It is suggested that in order to save trouble to the donors, arrangements be made with local photographers, to whom the negatives may be intrusted, to fill orders.

Register of Photographs Received in 1890.

The following is a complete register of the photographs collected previous to the Washington meeting. It contains the running numbers of the photographs by which they can be ordered, their labels, sizes, dates, the cost of duplicates, as well as the names of the photographers and the donors; also directions as to where duplicates and lantern slides may be obtained.

Professor J. F. Kemp presented 21 photographs, numbered from 1 to 21 inclusive. All but 18–21 were photographed by Mr. Kemp. Their size is 5 by 7 inches. They may be ordered of him at $0.10 unmounted, $0.12 mounted, postage extra.

1. Boss or knob of so-called porphyrite, associated with the elæolite-syenite near Beemerville, New Jersey. (Am. Jour. Sci., 3d ser., vol. XXXVIII, p. 130.) June, 1888.
2. The Sopris coal mines, near Trinidad, Colorado. The mines enter the hill just in the rear of the engine-house. September, 1888.
3. Coal mines and butte at Rouse, near Walsenburg, Colorado. Characteristic scenery of the eastern foothills. September, 1888.
4. View of Mount Sopris, western Colorado, from the Spring Gulch coal mines across Jerome park. The point of view is on the Laramie. The intervening upturned strata are Mesozoic and Paleozoic. August, 1888.
5. The Sunshine coal mines, Jerome park, northwestern Colorado. The Laramie sandstones show in section on the right, dipping westward. September, 1888.
6. Open cut and stopes at Pilot Knob, Missouri, showing the relations of the specular hematite to the porphyry, and also the thickness of the ore body. September, 1888.
7. Open cut at Pilot Knob, Missouri, showing the specular hematite interbedded in porphyry and slate. September, 1888.
8. Open cut at Iron Mountain, Missouri. Photograph taken on a very cloudy day. September, 1888.
9. Red Cambrian quartzite, as exposed in the quarries at Willard's ledge, Burlington, Vermont. Dip 10°–15° E. July, 1889.
10. Trap dike in red Cambrian quartzites at the Willard's ledge quarries, Burlington, Vermont. July, 1889.
11. Red Cambrian quartzite at the Red Rocks, just south of Burlington, Vermont. Dip 15°–20° E. The water is Lake Champlain. July, 1889.
12. Overthrow of Cambrian sandstone on Utica slate, Lone Rock point, just north of Burlington, Vermont. The water is Lake Champlain. July, 1889.

Nos. 94, 95, 96, 97, 99, 100, 101 are published in Fifth Ann. Rep. U. S. Geol. Survey, with plate numbers as below.

94. Mount Lyell, from the Tuolumne meadows, California. Pl. XXXVIII.
95. Tuolumne valley, California, showing upper limit of ancient glacier. Pl. LXI.
96. Mount Dana, California, from the west. A small glacier on northern slope, glaciated country to the right. Pl. XXXIV.
97. Mount Dana glacier, northern side of Mount Dana, California. Pl. XXXV.
98. Mount Dana glacier, northern side of Mount Dana, California.
99. Mount Dana glacier, northern side of Mount Dana, California. Pl. XXXVII.
100–101. Double plate. Mount Lyell glacier, northern side of Mount Lyell, California. Pl. XXXIX.
102. Leevining cañon, near Mono lake, California. A glaciated cañon with small terminal moraine in the foreground.

Glacial Phenomena of Mount Shasta, California. (Excepting 103 and 112 photographed by J. S. Diller, chiefly in July and August, 1884, Size, 8 x 10 inches.)

103. Mount Shasta from the western base, near the railroad station at Sissons. Size, 8 x 10 inches. Photographed by C. E. Dutton, July, 1885.
104. Mount Shasta from the north, after the first snowfall of September, 1884.
105. Near view of Mount Shasta from the north. Mount Shasta on the left is 2,000 feet higher than Shastina on the right The gray pile at the foot of the snow between them is the terminal moraine of the Whitney glacier. To the left of this is the terminal moraine of the Bulam glacier.
106. Whitney glacier, crevasses and moraine, northwestern slope of Mount Shasta.
107. Bulam glacier and moraine, northern slope of Mount Shasta.
108. Mount Shasta from the east.
109. Hotlum glacier and moraine, eastern slope of Mount Shasta.
110. Glaciated rocks, southeastern slope of Mount Shasta.
111. Moraine of late glacial field at western base of Lassen peak, California. Photographed August, 1885.
112. Glacial striæ, north Yallo Bally mount, Coast range, California. Photographed by J. Stanley-Brown, August, 1889.

Glacial Striæ, Bowlders, Avalanche.

113. Striated limestone bowlder from loess, one-half natural size, Norway, Iowa. Published in Eleventh Ann. Rep. U. S. Geol. Survey, pl. XLVI. Size, 8 x 10 inches. Photographed by W J McGee, 1888.
114. Perched bowlder, near Jura lake, Mono valley, California. Published in Eighth Ann. Rep. U. S. Geol. Survey, pl. XXXVIII. Size, 8 x 10 inches. Photographed by I. C. Russell, 1883.
115. Shore of Lake Ontario, at Pillar point, New York. Removal of glacial deposits by the waves has exposed a typical glaciated surface traversed by a few scratches ascribed to the grounding of icebergs. Same subject as No. 116. Published by T. C. Chamberlin, Seventh Ann. Rept. U. S. Geol. Survey, p. 166. Size, 4 x 4¾ inches. Photographed by G. K. Gilbert, 1885.
116. Shore of Lake Ontario at Pillar point, New York. The aberrant scratches are ascribed to the grounding of icebergs. Same subject as No. 115. Size, 4 x 4¾ inches. Photographed by G. K. Gilbert, 1885.
117. Bowlders in foreground, loess hills in background. S. E. ¼ S. E. ¼ sec. 3, T. 93 N., R. VIII W., Fayette county, Iowa. Size, 6 x 8 inches. Published in Eleventh Ann. Rep. U. S. Geol. Survey, pl. XLV. Photographed by W J McGee, 1888.

118. View on Brush creek, Gunnison county, Colorado, to show the swath cut by a snow-slide through a dense growth of spruce. Size, 8 x 10 inches. Photographed by C. Whitman Cross, October 8, 1885.

Wind Erosion. (Photographed by I. C. Russell, 1887. Size, 8 x 10 inches.)

119. Eolian erosion in rhyolite, Mono valley, California.
120. Sand dunes near Sleeping Bear bluff, eastern shore of Lake Michigan.
121. Forest formerly buried beneath drifting sand and now exposed by eolian erosion. High part of South Manitou island, Lake Michigan.

Topographic Features of Lake Shores, ancient and modern, Ontario Basin. (Photographed by G. K. Gilbert, 1885. Size, 4 x 4¾ inches.)

122. Shore of Lake Ontario, Griffin bay, New York. The waves have excavated a cliff from bowlder clay, but have not been able to remove the larger bowlders.
123. Shore of Lake Ontario, Griffin bay, New York. A barrier of shingle separates a lagoon from the lake.
124. On western shore of Cayuga lake, at East Varick, New York. A delta modified in outline through deflection of shore currents by a projecting pier.
125. Views of Iroquois shore, near Wolcott, New York. A sea-cliff, cut from a drumlin, appears just to the right of the center, and a spit running to the left bears a house and barn.
126. Portion of Iroquois shore, near Wolcott, New York. The camera stands on a spit and is turned toward a sea-cliff cut from a drumlin.
127. Iroquois shore, near Constantia, New York. The camera stands on a beach ridge of gravel. Compare modern beach in No. 123.
128. Iroquois shore, near Pierrepont manor, New York. Excavation of till by the waves left a cut terrace set with large bowlders. Compare with No. 122.
129. Iroquois shore, near Pierrepont manor, New York. Excavation of till by the waves left a cut terrace set with large bowlders. Compare with No. 122.
130. Iroquois shore, section of spit, 3 miles east of Watertown, New York. The open lake lay at the left, a bay at the right. The spit was accumulated by additions on the landward side.
131. Wall composed of limestone blocks rounded by wave action on an ancient shore of Lake Ontario, 5 miles east of Watertown, New York. 1890.

Topographic Features of Lake Shores, Michigan and Superior. (Photographed by I. C. Russell, 1887. Size, 8 x 10 inches.)

132. Sea-cliff in limestone, Mackinaw island, Michigan.
133. Sea-cliff in sandstone, small island near Marquette, Michigan.

Nos. 134, 135, 139, 142, 144, 145, 147 are published by G. K. Gilbert in Fifth Ann' Rep. U. S. Geol. Survey, with plate numbers as below.

134. Sea-cliff in hard sandstone, with beach beyond, Au Train island, Lake Superior. Pl. V.
135. Sea-cliff in bowlder clay, with beach in foreground, South Manitou island, Lake Michigan. Pl. III.
136. Sea-cliff in sand, with beach, Sleeping Bear point, eastern shore of Lake Michigan.
137. Sea-cliff in bowlder clay, South Manitou island, Lake Michigan.
138. Sea-cliff in bowlder clay, North Manitou island, Lake Michigan.
139. Beach of limestone pebbles, Mackinaw island, Michigan. Pl. VII.
140. Gravel spit, with driftwood, near Mackinaw island, Michigan.

141. A spit forming under water, western end of Bois Blanc island, Michigan. Mackinaw island in the distance.
142. Spit of shingle, Au Train island, Lake Superior. Pl. XIII.
143. Curved sand spit, southern channel, Strait of Mackinaw.
144. A recurved spit, "Duck point," Grand Traverse bay, Lake Michigan. Pl. IX.
145. Bar joining Empire and Sleeping Bear bluffs, eastern shore Lake Michigan. Pl. VIII.
146. Ancient sea-cliff of Lake Michigan, near Glen Arbor, Michigan.
147. Ancient sea-cliff of Lake Michigan, South Manitou island, Lake Michigan. Pl. VI.

Lacustrine Deposits, Sedimentary.

148. Sediments of Lake Lahontan, Humboldt valley near Rye Patch, Nevada. Published in Monograph No. XI, U. S. Geol. Survey, pl. XXII. Size, 8 x 10 inches. Photographed by I. C. Russell, 1882.
149. Lahontan lake-beds, bank of Humboldt river, Nevada. Size, 8 x 10 inches. Photographed by I. C. Russell, 1882.
150. Contorted lake-beds near southern margin of Mono lake, California. Published in Eighth Ann. Rep. U. S. Geol. Survey, pl. XXIV. Size, 8 x 10 inches. Photographed by I. C. Russell, 1883.
151. Deposit of infusorial earth 110 feet thick near Great bend of Pitt river, Shasta county, California. Size, 8 x 10 inches. Photographed by J. S. Diller, 1885.

Lacustrine Deposits, Chemical. (Photographed by I. C. Russell, 1883. Size, 8 x 10 inches.)

152. Lithoid, thinolitic and dendritic tufa deposited from the waters of Lake Lahontan, shore of Pyramid lake, Nevada.
153. Towers of calcareous tufa formed by sub-lacustral springs, shore of Mono lake, California. Published in Eighth Ann. Rep. U. S. Geol. Survey, pl. XXV.
154. Hillside coated with calcareous tufa deposited from Lake Lahontan, shore of Pyramid lake, Nevada.
155. Calcareous tufa deposited from the waters of Lake Lahontan, shore of Pyramid lake, Nevada.
156. Rocks coated with calcareous tufa, beach of oölitic sand. Shore of Pyramid lake, Nevada. Published in Monograph XI, U. S. Geol. Survey, pl. XIII.
157. Tufa domes formed by sub-lacustral springs. Published in Eighth Ann. Rep. U. S. Geol. Survey, pl. XXI.
158. An island of calcareous tufa deposited from the waters of Lake Lahontan, Pyramid lake, Nevada. Published in Monograph XI, U. S. Geol. Survey, pl. XXXVIII.
159. Pyramid island, Pyramid lake, Nevada; an island coated with calcareous tufa. Published in Monograph XI, U. S. Geol. Survey, pl. XI.

Spring Deposits.

160. Upper geyser basin, Yellowstone National Park. Crater of Old Faithful in the foreground at the right. In the distance the Castle and Grand geysers are in eruption. The formation is silicious sinter. Size, 10 x 13 inches. Photographed by W. H. Jackson.
161. Crater of the Castle geyser, Upper geyser basin, Yellowstone National Park. Silicious sinter. Size, 10 x 13 inches. Photographed by W. H. Jackson.
162. Crater of the Grotto geyser. Silicious sinter. Yellowstone National Park. Size, 10 x 13 inches. Photographed by W. H. Jackson.

163. Old Faithful in eruption. Upper geyser basin, Yellowstone National Park. Size, 10 x 13 inches. Photographed by W. H. Jackson.

164. Calcareous tufa bank, Cement creek, Gunnison county, Colorado. Face seen is 40 to 50 feet high, overhanging in places, forming grottoes. Size, 8 x 10 inches. Photographed by C. Whitman Cross, July 28, 1885.

165. Calcareous tufa deposit, near view of central portion of bank shown in No. 164. Size, 8 x 10 inches. Photographed by C. Whitman Cross, July 28, 1885.

166. Mammoth hot springs, Yellowstone National Park. Size, 10 x 13 inches. Photographed by W. H. Jackson.

167. Mammoth hot springs, Yellowstone National Park. Size, 10 x 13 inches. Photographed by W. H. Jackson.

Dismal Swamp Series. (Photographed by I. C. Russell, April, 1889. Size, 6 x 8 inches.)

Nos. 168, 169, 170, 171, 176, 178, 180, 183 published by Professor N. S. Shaler in Tenth Ann. Rep. U. S. Geol. Survey, with plate numbers as below.

168. View showing the general aspect of the swamp in the district where the forest is relatively dense. In the foreground a single elevated root arch of the black gum is plainly shown, also a great number of cypress knees. Pl. XXIX.

169. Southern margin of Dismal Swamp, 12 miles west of Elizabeth City, North Carolina, showing the general aspect of the swamp in the month of May. The spur-like projections in the foreground are the knees belonging to the roots of the large cypress on the left hand. The gnarled excrescences at its base exhibit one type of root arches. In the center of the picture is a single root arch of the common type. Pl. VIII.

170. View showing general aspect of the wide, swampy channels which connect the main Dismal swamp with the tributary morasses lying to the west. Pl. XV.

171. View of the swamp about a mile and a half east of Drummond lake, showing the ordinary condition of the wetter parts of the swamp in the growing season. Pl. IX.

172. Southern margin of the swamp near Elizabeth City, North Carolina.

173. View near the southern border of the main swamp near Elizabeth City, North Carolina.

174. View of Jericho ditch.

175. Cypress trees in the eastern part of Lake Drummond.

176. Cypress trees in the eastern part of Lake Drummond. Pl. X.

177. View of the western shore of Lake Drummond, showing the wall-like character of the forest growth.

178. View of Jericho ditch. The foliage on the right hand represents a cane-brake. The trees on the left hand of the picture are of second growth.

179. View of Jericho ditch.

180. View showing thinly wooded portion of the main swamp area. The trees are mostly of second growth; the surface bears a scanty growth of cane. Pl. XVI.

181. View showing the general aspect of the wide, swampy channels connecting the main Dismal swamp with tributary morasses lying to the west of that area.

182. View of Jericho ditch.

183. Dismal Swamp canal, looking southward from the village of Wallaceton. The land on either side has been reclaimed from the original condition of swamp. Pl. VII.

SEISMIC PHENOMENA.

Effects of the Charleston Earthquake. (Photographed under the direction of W J McGee by C. C. Jones, September 3–7, 1886. Size, 10 x 13 inches.)

Nos. 185, 188, 189, 199, 202, and 203, published by C. E. Dutton in Ninth Ann. Rep., U. S. Geol. Survey, with plate numbers as below.

212. Lateral view of sandstone dike, Dry creek, Tehama county, California. p. 414.

213. Sandstone dike penetrating Cretaceous sandstones and shales, Dry creek, Tehama county, California. The dike is 10 inches thick below.

214. Four small sandstone dikes penetrating Cretaceous shales on Dry creek, Tehama county, California. The dikes are each about 4 inches thick. Some are regular and others very irregular.

VOLCANIC PHENOMENA.

Scene of a late Volcanic Eruption in Northern California. (Photographed by J. S. Diller, 1888 and 1890. Size, 8 x 10 inches.)

Nos. 215–226, published in Bulletin 79, U. S. Geol. Survey, with the designations given below.

215. Model of cinder cone, lava field and ash-covered slopes. The cinder cone is 640 feet high, the crater is 240 feet deep, and the lava field is about 3 miles long. Snag lake, at the left end of the lava field, was formed by the lava dam. Fig. 1.

216. Lava field and cinder cone looking southwest across Lake Bidwell, Lassen peak in the distance. Pl. II.

217. The cinder cone from the south, earlier lava partly covered by volcanic sand. The dead trees extend down 7 feet through the volcanic sand to the original soil beneath. Pl. III.

218. The cinder from the east. Earlier lava near the cone is covered by volcanic sand; later lava in the foreground uncovered. Pl. IX.

219. Volcanic bombs at the base of cinder cone; the largest is 8 feet in diameter. Pl. IV.

220. The lava field looking southeast from the base of the cinder cone towards Snag lake. Pl. VIII.

221. Surface of lava field; breaking of the lava crust. Photographed by W. B. Smith. Pl. VII.

222. The tree projecting from beneath the lava was pushed over by the advancing lava. The dead tree on the left extends 10 feet down through the coating of volcanic sand to the original soil beneath. The living trees, some of which are about 200 years old, have grown up entirely since the eruption. Pl. XIV.

223. Lava dam which formed Snag lake at the time of the eruption and drowned the trees whose stumps are seen in the lake. Pl. XIII.

224. Snag lake, with lava dam in the distance and the stumps of drowned trees in the foreground. Pl. XII.

225. Lava front at the corner of Snag lake. Pl. VI.

226. Near view of lava blocks on edge of lava field. The lava is basalt, which is remarkable in containing numerous phenocrysts of quartz, which are uniformly distributed throughout the mass. The white spots seen in the lava are quartz. Pl. XVI.

227. Hand specimen of quartz basalt from lava field near Snag lake. The white spots are quartz.

Laccolitic Domes and Plugs of the Black Hills. (Photographed by I. C. Russell, 1888. Size, 6 x 8 inches.)

228. Little Sun Dance hill, South Dakota. A dome of Carboniferous limestone, with Jurassic and Triassic rocks on the outer bench. The upheaval is due to volcanic rocks injected far beneath.

229. Little Sun Dance hill, from the top of Sun Dance hill, South Dakota.

230. Little Sun Dance hill, South Dakota. Near view.

231. Sun Dance hill, South Dakota. The volcanic rock injected from beneath exposed by erosion.

Session of Wednesday, December 31.

Two sections were organized. The First Section was called to order at 9.35 o'clock a. m., by acting President Winchell, with W. M. Davis as acting Secretary.

The Auditing Committee, Messrs. J. S. Diller and E. T. Dumble, reported that the Treasurer's accounts had been examined and found correct.

The report was adopted and the committee discharged.

It was moved and voted that the Secretary should communicate to Dr. G. Brown Goode, in charge of the National Museum, the thanks of the Society for furnishing and operating the stereopticon used at this meeting.

Professor Raphael Pumpelly was called to the chair, and the first paper of the day was read by the acting President.

A LAST WORD WITH THE HURONIAN.

BY ALEXANDER WINCHELL.

There was no discussion of the paper, which will be found printed in full among the memoirs as pages 85–124 of this volume.

The next paper was—

COMPOSITION OF CERTAIN MESOZOIC IGNEOUS ROCKS OF VIRGINIA.

BY H. D. CAMPBELL AND W. G. BROWN.

It was discussed by W. M. Davis, J. E. Wolff, F. L. Nason, B. K. Emerson, and G. H. Williams. It is printed, with the discussion, as pages 339-348 of this volume.

The following paper was then presented:

THE STRUCTURE OF THE BLUE RIDGE NEAR HARPER'S FERRY.

BY H. R. GEIGER AND ARTHUR KEITH.

It was discussed by Bailey Willis, C. H. Hitchcock, G. K. Gilbert, C. D. Walcott, and Jed. Hotchkiss; and, with the discussion and plates 4 and 5, is printed as pages 155–164 of this volume.

The third paper was—

THE COAL FIELDS OF ALABAMA.

BY HENRY MCCALLEY.

It was discussed by I. C. White, C. W. Hayes, E. V. D'Invilliers, G. F. Becker, and J. R. Procter. An abstract of this paper, mainly relating to the wealth of the coal fields, is published in the Scientific American Supplement, vol. XXXI, pp. 12530–12531.

The fourth paper was—

THE CINNABAR AND BOZEMAN COAL FIELDS OF MONTANA.

BY W. H. WEED.

It was the subject of remarks by G. M. Dawson, and is published as pages 349–364, with plate 13, of this volume.

The fifth paper was on—

THE GEOLOGY OF MOUNT DIABLO, CALIFORNIA.

BY H. W. TURNER.

It was discussed by G. F. Becker. It is supplemented by notes on—

THE CHEMISTRY OF THE MOUNT DIABLO ROCKS.

BY W. H. MELVILLE.

The paper and supplement are printed, with plate 15, as pages 383–414 of this volume.

The sixth paper was read, in the absence of the author, by G. M. Dawson:

THE CARBONIFEROUS FLORA OF NEWFOUNDLAND.

BY SIR WILLIAM DAWSON.

The communication is printed as pages 529–540, plates 21 and 22, of this volume.

The following paper was then read:

GLACIAL LAKES IN CANADA.

BY WARREN UPHAM.

It is printed, with remarks by G. M. Dawson, on pages 243–276 of this volume.

The papers remaining upon the program were read by title only. They are as follows:

NOTES ON TWO MORAINES IN THE CATSKILL MOUNTAINS, NEW YORK.

BY J. C. SMOCK.

THE MELTING OF THE NORTHERN ICE-SHEET IN NORTHEASTERN IOWA.

BY W J MCGEE.

(This communication, with much other matter, appears in full in the Eleventh Annual Report of the Director of the United States Geological Survey, 1891, pages 187–577, with plates II–LXI.)

THE QUATERNARY FORMATIONS OF THE SOUTHWEST.

BY E. W. HILGARD.

GLACIAL GROOVES AT THE SOUTHERN MARGIN OF THE DRIFT.

BY P. MAX FOSHAY AND R. R. HICE.

This paper is printed as pages 457–464, with plate 18, of this volume.

TERTIARY AND POST-TERTIARY CHANGES OF THE ATLANTIC AND PACIFIC COASTS.

BY JOSEPH LE CONTE.

A NOTE ON THE MUTUAL RELATIONS OF LAND ELEVATION AND ICE ACCUMULATION DURING THE QUATERNARY PERIOD.

BY JOSEPH LE CONTE.

These two papers are printed as pages 323–330 of this volume.

ON A JOINTED EARTH AUGER FOR GEOLOGICAL EXPLORATION IN SOFT DEPOSITS.

BY N. H. DARTON.

The instrument exhibited is a modification of the form proposed by McGee in the Ninth Annual Report of the Director of the United States Geological Survey, for 1887-'88, pages 106-107. It consists of an ordinary carpenter's auger, 1¼ inches in diameter, welded to a short length of iron bar; a number of 3-foot lengths of ¼-inch iron pipe with threads and couplings, and a cross-head of ½-inch iron bar for a handle. In clays and sands borings have been made with this instrument to a depth of 40 feet, samples being secured at about each 6 inches. A detailed description of the instrument is given in American Geologist, volume VII, 1891, page 117.

ON THE OCCURRENCE OF DIAMONDS IN WISCONSIN.

BY GEORGE FREDERICK KUNZ

In October, 1890, Mr. G. H. Nichols, of Minneapolis, Minnesota, wrote to the editors of the "Engineering and Mining Journal"* stating that in a review of "Gems and Precious Stones of North America"† published in that journal no mention had been made of the finding of diamonds in Wisconsin, and adding that he had found several small ones there. The matter having been referred to me, I immediately put myself in communication with Mr. Nichols, and from him obtained the information which I now give.

In the summer of 1887 Mr. Nichols, in company with Mr. W. W. Newell and Mr. C. A. Hawn, of Rock Elm, prospected for gold on Plum creek, in Rock Elm township, Pearce county, Wisconsin. They employed some help, and, while sluicing for gold, one of their workmen detected a bright stone, which proved to be a diamond. This was in gravel which had been taken from the bank of the stream at a depth of some feet below water-level. Bad weather prevented the continuance of the work then, but as soon as favorable weather came they resumed their search, and Mr. Newell found one, while several were found by other members of the party. No more work was done in 1887, but in panning three miles further up the stream Mr. Newell found another diamond, which was very much distorted and off color.

In the summer of 1888 actual sluicing for gold was begun, and in the gravel that occurred at the washout four diamonds were found in three weeks' time. One was found on the surface of the gravel bed, and another came from material taken out of a pit some thirty rods from where the other was found, at a depth of five or six feet below the water-level. The most perfect stone was found by a workman, who secreted it. In 1889 prospecting was again resumed on the western branch of Plum creek, where Mr. Nichols found another diamond in a shovelful of gravel taken from the sluice. Two or three small ones were also found in the tailings.

Gold is found all along the main branches of Plum creek, as well as all along the smaller runs of their extreme headwaters from two to five miles from their confluence. From Mr. Nichols I received a series of specimens both of the gold-bearing sands in

* December 13, 1890, page 686.
† New York, 1890, page 336, plate 21.

For reporting discussions of the papers credit is hereby given as follows:

Reporting discussion on Archean, H. W. Turner; on Cambrian and Silurian, N. H. Darton; on Devonian and Carboniferous and on Paleobotany, C. S. Prosser; on Mesozoic and Tertiary, W. H. Weed; on Quaternary, C. Willard Hayes; on Petrography, J. E. Wolff.

Vice-President Winchell, the President-elect, made some closing remarks, and the Society adjourned, to meet in Washington, D. C., on August 24, 1891, at 10 o'clock a. m.

Register of the Washington Meeting, 1890.

The following Fellows were in attendance at the meeting:

Henry M. Ami.
George H. Barton.
George F. Becker.
Robert Bell.
Ezra Brainerd.
Walter A. Brownell.
Henry D. Campbell.
Franklin R. Carpenter.
J. H. Chapin.
William B. Clark.
Edward D. Cope.
C. Whitman Cross.
Nelson H. Darton.
William M. Davis.
George M. Dawson.
Joseph S. Diller.
Edward V. D'Invilliers.
Edwin T. Dumble.
George H. Eldridge.
Benjamin K. Emerson.
Samuel F. Emmons.
Herman L. Fairchild.
G. K. Gilbert.
Arnold Hague.
C. Willard Hayes.
Robert T. Hill.
Charles H. Hitchcock.
Jed. Hotchkiss.
Horace C. Hovey.
Edwin E. Howell.
Joseph P. Iddings.
Joseph F. James.
Arthur Keith.
Charles R. Keyes.
Frank H. Knowlton.
Daniel W. Langdon, Jr.
Josua Lindahl.
Henry McCalley.
W J McGee.
Othniel C. Marsh.
P. H. Mell.
George P. Merrill.
Henry B. Nason.
Edward Orton.
J. W. Powell.
John R. Procter.
Charles S. Prosser.
Raphael Pumpelly.
Israel C. Russell.
J. W. Spencer.
John J. Stevenson.
Henry W. Turner.
Warren Upham.
Charles D. Walcott.
Walter H. Weed.
David White.
Israel C. White.
Charles A. White.
George H. Williams.
Henry S. Williams.
Bailey Willis.
Alexander Winchell.
Newton H. Winchell.
John E. Wolff.
Robert S. Woodward.
G. Frederick Wright.

Total attendance, 66.

* EDWARD W. CLAYPOLE, D. Sc., Akron, O.; Professor of Geology in Buchtel College.

AARON H. COLE, A. M., Hamilton, N. Y.; Lecturer on Biology and Geology in Colgate University. December, 1889.

* JOHN COLLETT, A. M., Ph. D., Indianapolis, Ind.; lately State Geologist.

* THEODORE B. COMSTOCK, Tucson, Ariz.; Director Arizona School of Mines.

† GEORGE H. COOK, Ph. D., LL. D. (Died September 22, 1889.)

* EDWARD D. COPE, Ph. D., 2102 Pine St., Philadelphia; Professor of Geology in the University of Pennsylvania.

* FRANCIS W. CRAGIN, B. S., Topeka, Kansas; Professor of Geology and Natural History in Washburne College.

* ALBERT R. CRANDALL, A. M., Lexington, Kentucky; Professor of Geology in Agricultural and Mechanical College of Kentucky.

* WILLIAM O. CROSBY, B. S., Boston Society of Natural History, Boston, Mass.; Assistant Professor of Mineralogy and Lithology in Massachusetts Institute of Technology.

CHARLES WHITMAN CROSS, Ph. D., U. S. Geological Survey, Washington, D. C. May, 1889.

* MALCOLM H. CRUMP, Bowling Green, Kentucky; Professor of Natural Science in Ogden College.

* HENRY P. CUSHING, M. S., 786 Prospect St., Cleveland, Ohio.

T. NELSON DALE, Newport, R. I.; Assistant Geologist, U. S. Geological Survey. December, 1890.

* JAMES D. DANA, LL. D., New Haven, Conn.; Professor of Geology in Yale University.

* NELSON H. DARTON, United States Geological Survey, Washington, D. C.

* WILLIAM M. DAVIS, Cambridge, Mass.; Professor of Physical Geography in Harvard University.

GEORGE M. DAWSON, D. Sc., A. R. S. M., Geological Survey Office, Ottawa, Can.; Assistant Director of Geological and Natural History Survey of Canada. May, 1889.

Sir J. WILLIAM DAWSON, LL. D., McGill College, Montreal, Canada; Principal of McGill University. May, 1889.

FREDERICK P. DEWEY, Ph. B., 621 F St. N. W., Washington, D. C. May, 1889.

ORVILLE A. DERBY, M. S., Sao Paulo, Brazil; Director of the Geographical and Geological Survey of the Province of Sao Paulo, Brazil.

* JOSEPH S. DILLER, B. S., United States Geological Survey, Washington, D. C.

EDWARD V. D'INVILLIERS, E. M., 711 Walnut St., Philadelphia, Pa. December, 1888.

* EDWIN T. DUMBLE, Austin, Texas; State Geologist.

* WILLIAM B. DWIGHT, M. A., Ph. B., Poughkeepsie, N. Y.; Professor of Natural History in Vassar College.

* GEORGE H. ELDRIDGE, A. B., United States Geological Survey, Washington, D. C.

ROBERT W. ELLS, LL. D., Geological Survey Office, Ottawa, Canada; Field Geologist on Geological and Natural History Survey of Canada. December, 1888.

* BENJAMIN K. EMERSON, Ph. D., Amherst, Mass.; Professor of Geology in Amherst College.

* SAMUEL F. EMMONS, A. M., E. M., U. S. Geological Survey, Washington, D. C.

* HERMAN L. FAIRCHILD, B. S., Rochester, N. Y.; Professor of Geology and Natural History in University of Rochester.

J. C. FALES, Danville, Kentucky; Professor in Centre College. December, 1888.

WALDEMAR LINDGREN, U. S. Geological Survey, Washington, D. C.

ROBERT H. LOUGHRIDGE, Ph. D., Berkeley, Cal.; Assistant Professor of Agricultural Chemistry in University of California. May, 1889.

THOMAS H. MCBRIDE, Iowa City, Iowa; Professor of Botany in the State University of Iowa. May, 1889.

HENRY MCCALLEY, A. M., C. E., University, Tuscaloosa County, Ala.; Assistant on Geological Survey of Alabama. May, 1889.

RICHARD G. MCCONNELL, A. B., Geological Survey Office, Ottawa, Canada; Field Geologist on Geological and Natural History Survey of Canada. May, 1889.

* W J MCGEE, United States Geological Survey, Washington, D. C.

WILLIAM MCINNES, A. B., Geological Survey Office, Ottawa, Canada; Assistant Field Geologist, Geological and Natural History Survey of Canada. May, 1889.

PETER MCKELLAR, Fort William, Canada. August, 1890.

JULES MARCOU, 42 Garden St., Cambridge, Mass. December, 1888.

OLIVER MARCY, LL. D., Evanston, Cook Co., Illinois; Professor of Natural History in Northwestern University. May, 1889.

OTHNIEL C. MARSH, Ph. D., LL. D., New Haven, Conn.; Professor of Paleontology in Yale College. May, 1889.

P. H. MELL, M. E., Ph. D., Auburn, Ala.; Professor of Geology and Natural History in the State Polytechnic Institute. December, 1888.

* FREDERICK J. H. MERRILL, Ph. D., State Museum, Albany, N. Y.; Assistant State Geologist and Assistant Director of State Museum.

GEORGE P. MERRILL, M. S., U. S. National Museum, Washington, D. C.; Curator of Department of Lithology and Physical Geology. December, 1888.

JAMES E. MILLS, B. S., 2106 Van Ness Ave., San Francisco, Cal. December, 1888.

* ALBRO D. MORRILL, A. M., M. S., Athens, Ohio; Professor of Biology and Geology in Ohio University.

THOMAS F. MOSES, M. D., Urbana, Ohio; President of Urbana University. May, 1889.

* FRANK L. NASON, A. B., 5 Union St., New Brunswick, N. J.; Assistant on Geological Survey of New Jersey.

* HENRY B. NASON, Ph. D., M. D., LL. D., Troy, N. Y.; Professor of Chemistry and Natural Science in Rensselaer Polytechnic Institute.

* PETER NEFF, A. M., 401 Prospect St., Cleveland, Ohio.

* JOHN S. NEWBERRY, M. D., LL D., Columbia College, New York city; Professor of Geology and Paleontology in Columbia College.

FREDERICK H. NEWELL, B. S., U. S. Geological Survey, Washington, D. C. May, 1889.

* EDWARD ORTON, Ph. D., LL. D., Columbus, Ohio; State Geologist and Professor of Geology in the State University.

*AMOS O. OSBORN, Waterville, Oneida Co., N. Y.

*† RICHARD OWEN, LL. D. (Died March 24, 1890.)

* HORACE B. PATTON, Ph. D., New Brunswick, N. J.; Assistant Professor of Geology and Mineralogy in Rutgers College.

RICHARD A. F. PENROSE, Jr., Ph. D., Little Rock, Arkansas; Assistant on Arkansas Geological Survey. May, 1889.

JOSEPH H. PERRY, Worcester, Mass.; Professor of Natural Sciences in the Worcester High School. December, 1888.

* WILLIAM H. PETTEE, A. M., Ann Arbor, Mich.; Professor of Mineralogy, Economical Geology, and Mining Engineering in Michigan University.

* FRANKLIN PLATT, 615 Walnut St., Philadelphia, Pa.

*CHARLES R. VAN HISE, M. S., Madison, Wis.; Professor of Mineralogy and Petrography in Wisconsin University, Geologist U. S. Geological Survey.

*ANTHONY W. VOGDES, Fort Canby, Astoria, Or.; Captain Fifth Artillery, U. S. Army.

CHARLES WACHSMUTH, M. D., Burlington, Iowa. May, 1889.

*MARSHMAN E. WADSWORTH, Ph. D., Houghton, Mich.; State Geologist, Director of Michigan Mining School.

*CHARLES D. WALCOTT, U. S. National Museum, Washington, D. C.; Paleontologist U. S. Geological Survey.

LESTER F. WARD, A. M., U. S. Geological Survey, Washington, D. C.; Paleontologist U. S. Geological Survey. May, 1889.

WALTER H. WEED, M. E., U. S. Geological Survey, Washington, D. C. May, 1889.

DAVID WHITE, U. S. Geological Survey, Washington, D. C. May, 1889.

*ISRAEL C. WHITE, Ph. D., Morgantown, W. Va.; Professor of Geology in West Virginia University.

*CHARLES A. WHITE, M. D., U. S. National Museum, Washington, D. C.; Paleontologist U. S. Geological Survey.

*ROBERT P. WHITFIELD, Ph. D., American Museum of Natural History, 77th St. and Eighth Ave., New York city; Curator of Geology and Paleontology in American Museum of Natural History.

*EDWARD H. WILLIAMS, Jr., A. C., E. M., 117 Church St., Bethlehem, Pa.; Professor of Mining Engineering and Geology in Lehigh University.

*GEORGE H. WILLIAMS, Ph. D., Johns Hopkins University, Baltimore, Md.; Professor of Inorganic Geology in Johns Hopkins University.

*HENRY S. WILLIAMS, Ph. D., Ithaca, N. Y.; Professor of Geology and Paleontology in Cornell University.

*J. FRANCIS WILLIAMS, Ph. D., Salem, N. Y.

*SAMUEL G. WILLIAMS, Ph. D., Ithaca, N. Y.; Professor in Cornell University.

BAILEY WILLIS, U. S. Geological Survey, Washington, D. C. December, 1889.

*†ALEXANDER WINCHELL, LL. D. (Died February 19, 1891.)

*HORACE VAUGHN WINCHELL, 10 State St., Minneapolis, Minn.; Assistant on Geological Survey of Minnesota.

*NEWTON H. WINCHELL, A. M., Minneapolis, Minn.; State Geologist; Professor in University of Minnesota.

*ARTHUR WINSLOW, B. S., Jefferson City, Mo.; State Geologist.

JOHN E. WOLFF, Ph. D., Harvard University, Cambridge, Mass.; Instructor in Petrography, Harvard University. December, 1889.

ROBERT SIMPSON WOODWARD, C. E., U. S. Coast and Geodetic Survey, Washington, D. C. May, 1889.

*G. FREDERICK WRIGHT, D. D., Oberlin, Ohio; Professor in Oberlin Theological Seminary.

LORENZO G. YATES, M. D., Santa Barbara, Cal. December, 1889.

Summary.

Original Fellows	112
Elected Fellows	96
Aggregate	208
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